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Review of Lake Trout Rehabilitation Efforts in Canadian Waters of Lake Huron, 1974 to 2006

Upper Great Lakes Management Unit - Lake Huron
March 2010

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Lake Huron Office
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Ontario Ministry of Natural Resources
Upper Great Lakes Management Unit,
Lake Huron Office

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EXECUTIVE SUMMARY

Lake trout (*Salvelnus namaycush*), were the dominant coldwater predator in Lake Huron until population crashes occurred in the 1940s and 1950s. Since that time, international rehabilitation efforts directed at lake trout have been implemented. An underlying theme to these rehabilitation efforts is that of a progression or 'continuum' through rehabilitation. Lake trout rehabilitation is expected to follow a progression from development of a population and subsequent spawning stock using stocked fish, to production of wild fish through natural reproduction by stocked adults, to a population that is entirely self sustaining.

To further lake trout rehabilitation efforts in Ontario waters of Lake Huron, the Ontario Ministry of Natural Resources drafted the 1996 Lake Trout Rehabilitation Plan for Lake Huron (Canadian jurisdiction) using this continuum concept for guidance. The 1996 Plan called for regular reviews of progress. As a result, this document presents a review of progress in the Lake Trout Rehabilitation Zones identified in the 1996 Plan, as well as a review of the 1996 Plan itself. Where necessary, changes to the 1996 Plan are recommended to further refine the rehabilitation process for the future.

Using the 1996 Plan objectives and evaluation criteria as benchmarks, progress towards rehabilitation in each of the 16 LTRZs is described. With a few exceptions, age distributions were truncated in most LTRZs with few fish observed older than six years of age. This suggests that adult mortality is an impediment to rehabilitation in many parts of Lake Huron. However, where adult mortality has been controlled, signs of rehabilitation have been observed. For example, the Parry Sound remnant lake trout stock has been successfully rehabilitated and natural reproduction has been observed in both Owen Sound and South Bay.

Upon review, the intent of the goal and objectives from the 1996 plan were deemed to be sound. However, revisions to the three objectives have been recommended that more closely relate them to the progression through rehabilitation. These revised objectives more closely reflect timelines associated with rehabilitation, and how these timelines differ between individual LTRZs as a result of differences in stocking history, stocking density, total annual mortality, and age to maturity.

In addition to recommendations specific to the goals and objectives, recommendations for changes to rehabilitation strategies (i.e. stocking and exploitation control), evaluation criteria, and assessment tactics are made. Generally, these recommendations provide direction for implementation of rehabilitation activities and provide for more discreet, measurable indicators of progress. As a whole, these recommendations are expected to form the basis for a revised rehabilitation plan for Ontario waters of Lake Huron.

INTRODUCTION

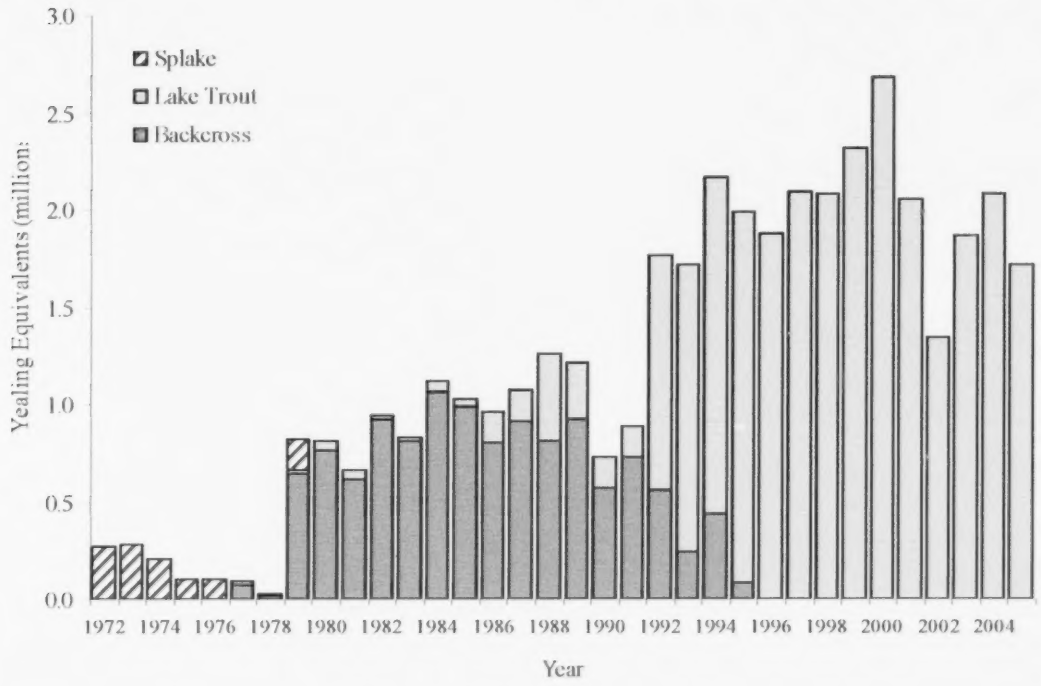
Lake trout were historically the top coldwater predator in all three of the upper Laurentian Great Lakes, including Lake Huron. It has been suggested that up to 12 different strains or types of lake trout historically existed in Lake Huron (Loftus 1980). Unfortunately, lake trout populations in all three upper lakes began to decline in the early 1940s and eventually collapsed in Lake Huron in the 1950s due to several stresses including the invasion of the parasitic sea lamprey (*Petromyzon marinus)*, the loss of native food sources (lake herring (*Coregonus artedii*)), and exploitation (Coble et al. 1990; Eshenroder et al 1992). In Lake Huron only two populations survived the collapse, one in Parry Sound and the other in Iroquois Bay.

Shortly after the collapse of lake trout, efforts began to rehabilitate this species. Lake trout rehabilitation has been defined as the "re-establishment of lake trout populations that, through natural reproduction, can sustain themselves under controlled exploitation" (OMNR 1996). These rehabilitation efforts have been supported by provincial, state, and federal initiatives including lake wide, international lake trout rehabilitation plans (Argyle et al. 1991; Ebener 1998) and Fish Community Objectives (FCOs) for Lake Huron (Desjardine et al. 1995). Initially, two major programs were developed to aid in the recovery of lake trout: sea lamprey control and stocking initiatives.

The Great Lakes Fishery Commission (GLFC) was established in 1955 to facilitate international programs including rehabilitation of lake trout and sea lamprey control in the Great Lakes. Over the past 50 years, the GLFC, along with both U.S. and Canadian federal fisheries agencies, have spent considerable time and effort attempting to reduce sea lamprey abundance in the Great Lakes. A number of techniques have been utilized including the use of sea lamprey barriers on tributaries, adult trapping, lampricide treatment, and a sterile male release program (http://www.glfc.org/sealamp/how.php, accessed on November 8, 2007).

The second major component in lake trout rehabilitation involved stocking lake trout. Initial plantings in Lake Huron in the early 1950s had poor survival due to excessive sea lamprey mortality. Subsequent stocking of splake (*Salvelinus sp.*), an early-maturing lake trout/brook trout (*Salvelinus fontinalis*) hybrid, began in 1969 and continued to 1977 (Spangler and Berst 1976). In Ontario waters, poor survival and the absence of natural reproduction by splake prompted the infusion of more lake trout genes in the hybrid through backcrossing in Ontario's hatchery system. Backcross lake trout were first planted in northern Georgian Bay in 1978 and in 1979 stocking was expanded to include all of Georgian Bay. The continued absence of natural reproduction and reduced lamprey abundance in Ontario waters lead to a decision to stock pure strain lake trout exclusively by 1995. Since then, an average of two million pure strain lake trout has been stocked annually in Ontario waters of Lake Huron (Figure 1).

Figure 1. Lake trout stocking history for Canadian waters of Lake Huron, 1979 to 2006.



In 1996, the Ontario Ministry of Natural Resources (OMNR) Upper Great Lakes Management Unit (UGLMU) (then called the Lake Huron Management Unit) published a Lake Trout Rehabilitation Plan for Lake Huron (Canadian jurisdiction) (OMNR 1996) (hereafter called the 1996 Plan). The purpose of the 1996 Plan was to develop a strategy for the rehabilitation of lake trout in Ontario waters of Lake Huron. The document established goals, objectives, specific strategies, and tactics, for rehabilitation of lake trout throughout the lake. It also provided a synopsis of the historical harvest and abundance of lake trout in Lake Huron and confirmed the importance of this species to the stability and integrity of the Lake Huron fish community (OMNR 1996). Prior to publication, the 1996 Plan was reviewed and supported by a wide spectrum of stakeholders, individuals, and communities, around Lake Huron (McLeish 1996). The 1996 Plan also recognized the need for evaluation and called for a review every five years.

Since 1996, the Plan has guided lake trout rehabilitation activities in Ontario waters of Lake Huron. These rehabilitation actions include continued stocking, focused assessment and management activities for the Iroquois Bay and Parry Sound remnant stocks, and assessment of progress in other areas of the lake.

The purpose of this report is to review progress made in rehabilitating lake trout in Lake Huron since the 1996 Plan. The specific goals of this report are to:

1) present an overview of all lake trout data from Canadian waters of Lake Huron up to 2006

2) assess long term lake trout rehabilitation progress using the 1996 Plan objectives, strategies, and evaluation criteria as benchmarks for gauging progress
3) evaluate the goal, objectives, strategies and criteria presented in the 1996 Plan
4) make recommendations for changes to items in #3 where appropriate, for consideration in a revised lake trout rehabilitation plan for Ontario waters of Lake Huron.

REVIEW OF LAKE TROUT REHABILITATION EFFORTS

Lake trout rehabilitation has a long history on Lake Huron (OMNR 1989, 1990). As management actions and recommendations became more involved and complex through time, it was clear that a structured rehabilitation plan was needed.

The first formal lake trout rehabilitation plan for Lake Huron listed several potential rehabilitation strategies (Argyle et al. 1991). This plan also made several very general recommendations including monitoring and assessment guidelines that described what type of data should be collected and how it should be analyzed. It also defined a limited number of evaluation criteria (defined as strategies) that could be used to evaluate progress such as stocking densities, sea lamprey control targets, and targets for a number of population parameters. However, the options were limited and protocols for evaluation were not clearly defined.

The OMNR's 1996 Plan for Canadian waters of Lake Huron was considerably more comprehensive. After detailed review of existing strategic plans and documents, evaluation of lake trout rehabilitation efforts elsewhere, and public consultation around the lake, the Lake Trout Rehabilitation Plan for Lake Huron (Canadian jurisdiction) was published by OMNR in 1996.

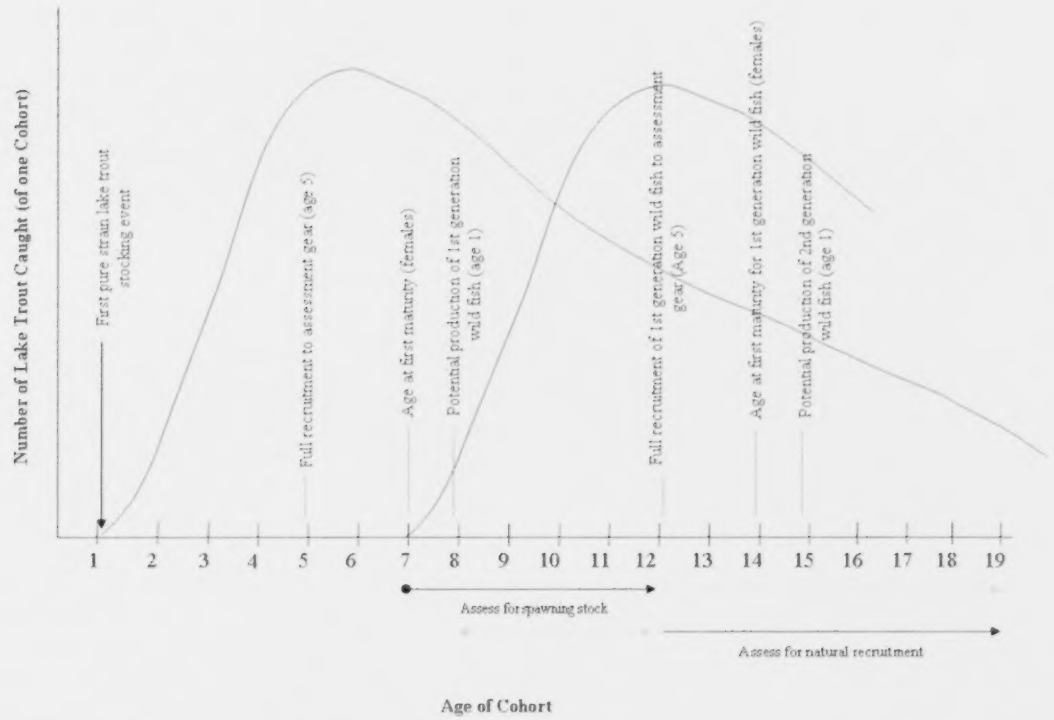
The 1996 Plan presented a framework for rehabilitation of lake trout in Canadian waters. The document listed eight different evaluation criteria which could be applied to the 16 different rehabilitation zones identified in the plan. This plan included all of the recommendations which were initially made by Argyle et al. (1991), and listed additional assessment and management strategies for evaluating lake trout rehabilitation. Critical life stages were identified and key parameters were selected to help measure progress. However, as in the first lake trout rehabilitation plan, there were no explicit assessment methodologies presented or suggestions for how or when the data should be collected on a lake wide basis.

The Lake Trout Rehabilitation Guide for Lake Huron (Ebener 1998) took the rehabilitation process one step further. Using data collected 10 to 15 years prior to publication, Ebener (1998) refined and in some cases re-defined the objectives and evaluation criteria that had been suggested by the two preceding plans. The Lake Trout Rehabilitation Guide for Lake Huron also incorporated many of the findings from the RESTORE Conference (Selgeby et al. 1995) in its recommendations. One important parameter identified by Ebener (1998) was the importance of lake trout habitat shallower than 40 fathoms. Habitats shallower than 40 fathoms were thought to be the primary areas used by the lake trout strains stocked into Lake Huron and as such, rehabilitation efforts and assessment should be focused in these areas.

One fundamental concept identified in virtually every lake trout rehabilitation plan developed for the Great Lakes (including the three documents discussed above) is the progression from a population that is entirely dependent on hatchery input, to one that has limited natural reproduction, to a population that is entirely self sustaining and is supported by natural reproduction alone. This concept is displayed graphically in Figure 2. Movement through these three distinct phases can be categorized by short-term, mid-term and long-term objectives, as

attainment of each objective indicates that each phase of rehabilitation has been successfully completed.

Figure 2. Lake trout rehabilitation timeline based on stocking, growth and the maturity rate of lake trout stocked in Lake Huron.


Number of Lake Trout Caught (of one Cohort)
First pure strain lake trout stocking event
Full recruitment to assessment gear (age 5)
Age at first maturity (females)
Potential production of 1st generation wild fish (age 1)
Full recruitment of 1st generation wild fish to assessment gear (Age 5)
Age at first maturity for 1st generation wild fish (females)
Potential production of 2nd generation wild fish (age 1)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
Assess for spawning stock
Assess for natural recruitment
Age of Cohort

The short-term objective of any lake trout rehabilitation plan is to establish a sufficiently large, mature spawning stock of hatchery origin spawners. A sufficiently large spawning stock is required to maximize the probability of reproduction over suitable habitat and ultimately facilitate successful reproduction over large areas. The establishment of a spawning stock is influenced by a number of factors including stocking density, total mortality and age to maturity.

Once a sufficiently large spawning stock has been established, the focus of rehabilitation switches to the mid-term objective of detecting and monitoring natural reproduction which is expected after the short term objective is met. Impediments to natural reproduction (assuming that a sufficient spawning stock exists) include lack or a loss of spawning habitat, reproductive impairment, and/or predation on critical life stages (eggs, larva or juveniles).

The final stage of lake trout rehabilitation is characterized by the establishment of a completely self-sustaining population. This stage is characterized by careful management designed to protect and enhance naturally produced fish, while simultaneously reducing the proportion of

stocked fish in the population. This objective is often achieved by ramping down or eliminating hatchery inputs and implementing management actions to protect wild fish.

Ontario's 1996 Plan included short-, mid-, and long-term objectives that reflected these three phases for lake trout rehabilitation (OMNR 1996) and included specific targets or biometrics that could be used to measure progress towards these objectives. The measures outlined in the 1996 Plan serve as benchmarks for the following review of progress towards lake trout rehabilitation in Ontario waters of Lake Huron.

LAKE TROUT REHABILITATION ZONES

To facilitate focused efforts, the 1996 Plan defined specific areas that would be targeted for rehabilitation. These areas were termed Lake Trout Rehabilitation Zones (LTRZs) (Table 1; Figure 3). These zones possessed a variety of key characteristics required for successful rehabilitation of lake trout including suitable spawning, summer and home range habitat, low sea lamprey abundance (in most cases), good water quality, and the potential for controlled exploitation. They were generally small in size and relatively accessible for stocking. To further facilitate rehabilitation efforts, the 1996 Plan assigned a protection class and rehabilitation status category to each zone.

Protection class defined the degree of protection from exploitation provided through regulation. It included three distinct classifications. LTRZs having a primary classification were regulated as sanctuaries. No fishing, either recreational or commercial, is allowed in sanctuaries. Lake trout in LTRZs with a secondary classification were to be protected from excessive exploitation through implementation of restrictive license conditions and regulations. These regulations were intended to be more restrictive than the normal regulations for lake trout in other areas of the lake. Lake trout in LTRZs with a tertiary classification were protected by existing commercial and recreational fishing regulations.

While all LTRZs were thought to be suitable for rehabilitation based on their physical and biological attributes, significant obstacles to rehabilitation such as high lamprey abundance or the presence of large gill net fisheries were known to occur in some areas. These LTRZs were classified as deferred, and stocking and other rehabilitation activities were suspended in these areas. Deferred LTRZs maintained their designation as LTRZs due to the abundance of spawning habitat and historical evidence of lake trout spawning populations in these zones. Three LTRZs were classified as deferred in the 1996 Plan. The remaining LTRZs were classified as active and were the focus of subsequent rehabilitation efforts after the 1996 Plan was implemented.

Table 1. Lake Trout Rehabilitation Zones for Canadian waters of Lake Huron as presented in OMNR (1996).

Zone Number	Rehabilitation Zone	Basin	Area (ha)	Protection Class	Rehabilitation Status
1	Western North Channel	North Channel	60,705	Tertiary	Deferred
2	Darch and Bedford Islands	North Channel	89,034	Secondary	Active
3	Heywood Island	Georgian Bay	30,352	Secondary	Active
4	Grand Bank/ Dawson Rock	Georgian Bay	80,940	Primary	Active
5	Iroquois Bay	Georgian Bay	496	Secondary	Active
6	Parry Sound	Georgian Bay	8,903	Secondary	Active
7	Limestones	Georgian Bay	80,940	Primary	Active
8	Watchers	Georgian Bay	60,000	Secondary	Active
9	Southeast Georgian Bay (east of Owen Sound)	Georgian Bay	89,034	Secondary	Active
10	Southwest Georgian Bay (west of Owen Sound)	Georgian Bay	101,175	Secondary	Active
11	Point Clark	Lake Huron	151,762	Secondary	Active
12	Bruce Peninsula	Lake Huron	60,705	Tertiary	Deferred
13	Bruce Archipelago	Lake Huron	80,940	Secondary	Active
14	Northern Lake Huron/Providence Bay	Lake Huron	145,692	Tertiary	Deferred
15	South Bay	Lake Huron	8,600	Secondary	Active
16	Six Fathom Bank	Lake Huron	37,552*	Primary	Active

* Canadian waters only (Total area=116,541 ha)

Figure 3. Map of original Lake Trout Rehabilitation Zones for Canadian waters of Lake Huron (Figure 4 from OMNR 1996).

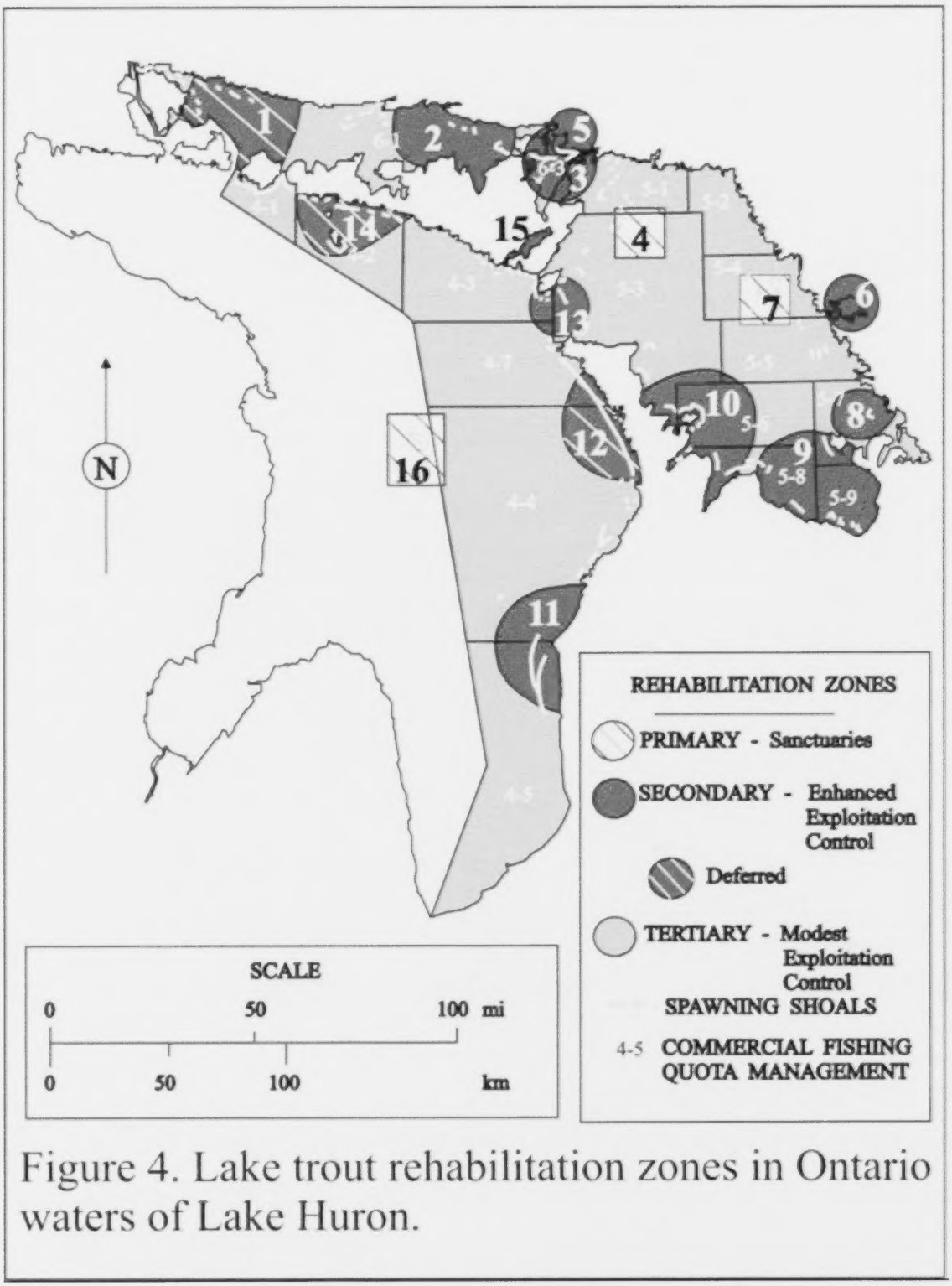


Figure 4. Lake trout rehabilitation zones in Ontario waters of Lake Huron.

SUMMARY OF REHABILITATION EFFORTS IN INDIVIDUAL LAKE TROUT REHABILITATION ZONES

A number of criteria for evaluating progress towards lake trout rehabilitation were proposed in Argyle et al. (1991), OMNR (1996), and Ebener et al. (1998) and the following summaries incorporate a number of these measures. For each zone, a summary of the stocking history and resulting stocking densities is presented, along with a summary of the attributes of the resultant population including trends in relative abundance, age structure, estimates of total mortality, lamprey wounding rates, and age to maturity. Stocking densities (number of lake trout stocked per area of LTRZ) are calculated based on the number of fish stocked within the revised LTRZ boundaries presented in Figure 4. The areas used when calculating stocking densities differ from those presented in the 1996 Plan as the curved boundaries used in the 1996 Plan did not conform to the grid based reporting structure used by the UGLMU. Where fish lacking fin clips (presumably wild) have been observed, the potential for natural reproduction is discussed. Using these measures, the stage of rehabilitation attained in each LTRZ is described.

Progress towards the short-term rehabilitation objective, establishing a spawning stock of hatchery origin, was assessed through trends in Catch Per Unit Effort (CPUE) and attributes of the age structure. An increasing trend in CPUE, in either commercial and/or assessment gear was interpreted as an indication of increasing abundance over time. With respect to the age structure, the number of age classes present provided a strong indication of the presence (or absence) of a spawning stock in a LTRZ. The age distribution was also used to estimate total annual mortality as excessive adult mortality was often manifested as a chronically truncated age distribution. Collectively, an increasing trend in CPUE and the presence of a broad, stable age distribution were thought to indicate that the short-term rehabilitation objective had been met.

The mid-term rehabilitation objective, successful natural reproduction, was inferred through the presence of unclipped (and presumably wild) fish in either assessment and/or commercial fishing gear. LTRZs that consistently had a high proportion (i.e. 25-50%) of unclipped fish were considered to have satisfied the mid-term rehabilitation objective. Progress in LTRZs with proportions of unclipped fish below 10% was interpreted with caution as Ebener (2000) and Madenjian (2004) suggested that in some cases, the failure rate for fin clipping might exceed 5 % in U.S. hatcheries.

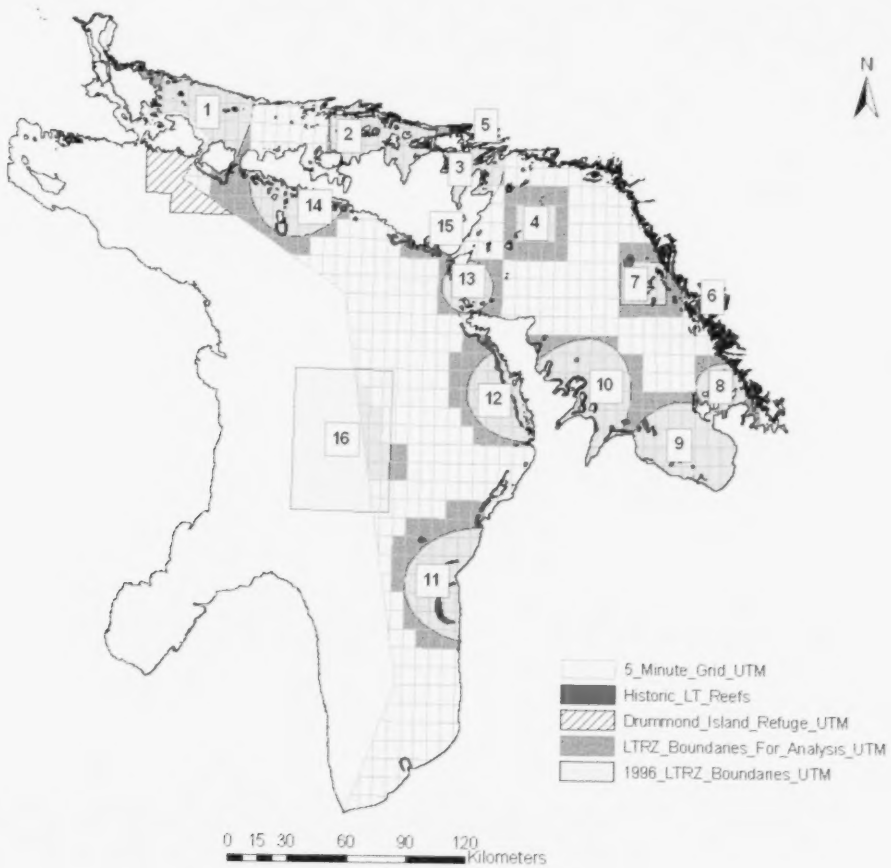
The long-term rehabilitation objective, the establishment of a completely self sustaining population of lake trout was inferred from indicators that were consistent with a stable, naturalized population. An increasing trend in the proportion of unclipped fish in the population, approaching 100% unclipped, was the key indicator of attainment of the long term rehabilitation objective. This was further supported if other population parameters such as abundance (as determined through CPUE parameters) and age structure remained stable after the termination of stocking. When sufficient data were available, the achievement of the long-term objective was confirmed through simulations and population modeling (Reid et al. 2001).

Data sources used to calculate these metrics for each LTRZ include commercial harvest, onboard commercial catch sampling, independent community index assessments, lake trout spawning population assessments, and recreational fishery assessment programs. The commercial data

utilized in this review were almost entirely from large-mesh (≥4.5") gill net fisheries. This generally represented more than 95% of the lake trout harvested by the commercial fishery. Only known-aged fish (fish with either coded-wire tags (CWTs) or year-specific clip codes) were used in age dependent analyses and, in cases where data were not available to differentiate between splake, backcross and lake trout, the term "*Salvelinus* sp." is used. Data up to and including 2006 are summarized in this report.

Lastly, the spatial aspects of the data summarized in this document differ slightly from LTRZ boundaries as presented in the 1996 lake trout rehabilitation plan. These modified boundaries for LTRZs were used to accommodate the grid based reporting structure used by the UGLMU (Figure 4).

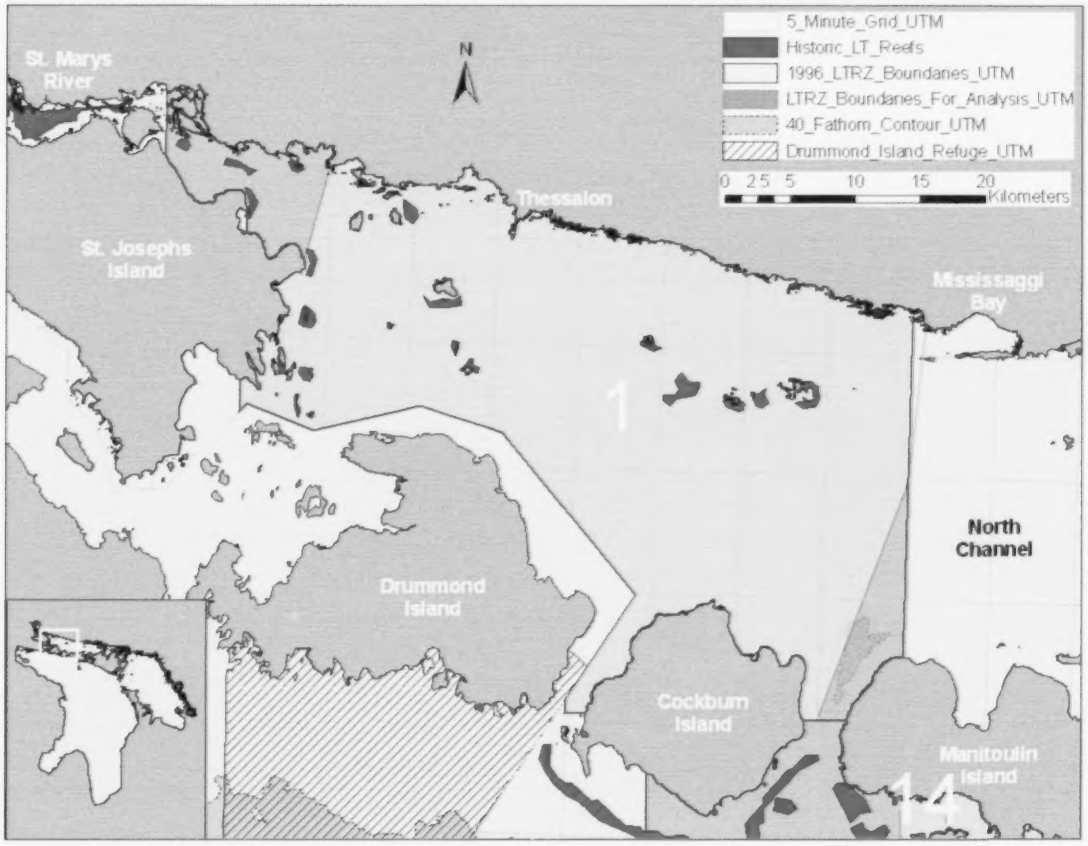
Figure 4. Lake Trout Rehabilitation Zones defined using a 5 minute grid system in relation to LTRZ boundaries as presented in OMNR (1996).



Lake Trout Rehabilitation Zone 1

Lake Trout Rehabilitation Zone 1 is located in the western end of the North Channel (Figure 5). It encompasses all the Canadian waters from the eastern shore of St. Joseph Island, eastward to a line running between the western end of Manitoulin Island and the opening to Mississaugi Bay. This LTRZ lies in close proximity to the Drummond Island Refuge, a priority lake trout rehabilitation zone in US waters.

Figure 5. The location of LTRZ 1, its boundaries according to the 1996 Lake Trout Rehabilitation Plan for Lake Huron (Canadian jurisdiction) (beige), the area assessed for this review (both beige and dark grey), lake trout spawning shoals, the 40 fathom contour, and the location of the Drummond Island Refuge.



LTRZ 1 was identified in the 1996 Plan as a deferred zone due to high sea lamprey abundance. As such, the zone was assigned a tertiary protection class.

Commercial fisheries in this area target walleye (*Sander vitreus*) close to St. Joseph's Island and some lake whitefish (*Coregonus clupeaformis*). Recreational fisheries target Chinook salmon (*Oncorhynchus tshawytscha*) in the offshore waters as well as walleye and lake herring (also known as ciscoe) (*Coregonis artedii*) closer to St. Josephs Island and the St. Mary's River.

As a deferred site, LTRZ 1 has not been actively stocked. A single stocking event did occur in 2002 in this zone when just over 180 000 Michipicoten strain lake trout were stocked near Thessalon (Figure 23). This stocking event was in response to hatchery difficulties and not part of any long term stocking strategy.

Lake trout found in this LTRZ are generally from an adjacent LTRZ (LTRZ 2) in the North Channel and several stocking sites in U.S. waters of northern Lake Huron. Coded wire tags recovered from fish in this zone suggest that some fish stocked in the Drummond Island Refuge move into the North Channel. A small number of fish stocked on Six Fathom Bank in the main basin of Lake Huron (LTRZ 16) and in northern Lake Michigan have also been recovered in this LTRZ.

The primary source of information in this LTRZ is from sampling commercial catches and from reported commercial fishing activities. Overall abundance of lake trout in this LTRZ is much lower than other LTRZs in the lake. There have been relatively few wild (unclipped) lake trout sampled from this zone. Small sample sizes have made it difficult to estimate mortality on an annual basis but using data combined over the past 10 years suggests that mortality has generally been in excess of 50%. Few fish older than six years of age have been observed in this LTRZ.

Sea lamprey marking rates continue to be extremely high in this LTRZ, averaging 28.0 marks per 100 fish over the past decade. This is much higher than the lake wide average for the same period (6.1 marks per 100 fish) and well above the target generally used by sea lamprey control agencies of 5.0 marks per 100 fish (Desjardine et al. 1995; Horns et al. 2003; Ebener 2005). It should be noted that sample sizes used to produce these sea lamprey wounding estimates were very low.

Current Status

This LTRZ has yet to achieve the first objective of lake trout rehabilitation, establishing a sufficiently large spawning stock. As a deferred zone, no rehabilitation progress was expected. While migration into this LTRZ does occur from a number of stocking locations, this is not sufficient to establish a spawning stock in the area. There is also little evidence of natural reproduction of lake trout in this LTRZ.

Increased sea lamprey treatment in the St. Mary's River began in 1998 (Department of Fisheries and Oceans unpublished data) which should have reduced lamprey mortality by 2000. Lower marking rates were observed in the North Channel between 2000 and 2006, but levels are still well above target values, partly because the number of lake trout is low, causing a concentration of attacks on the few large lake trout present in the zone.

Recommendations

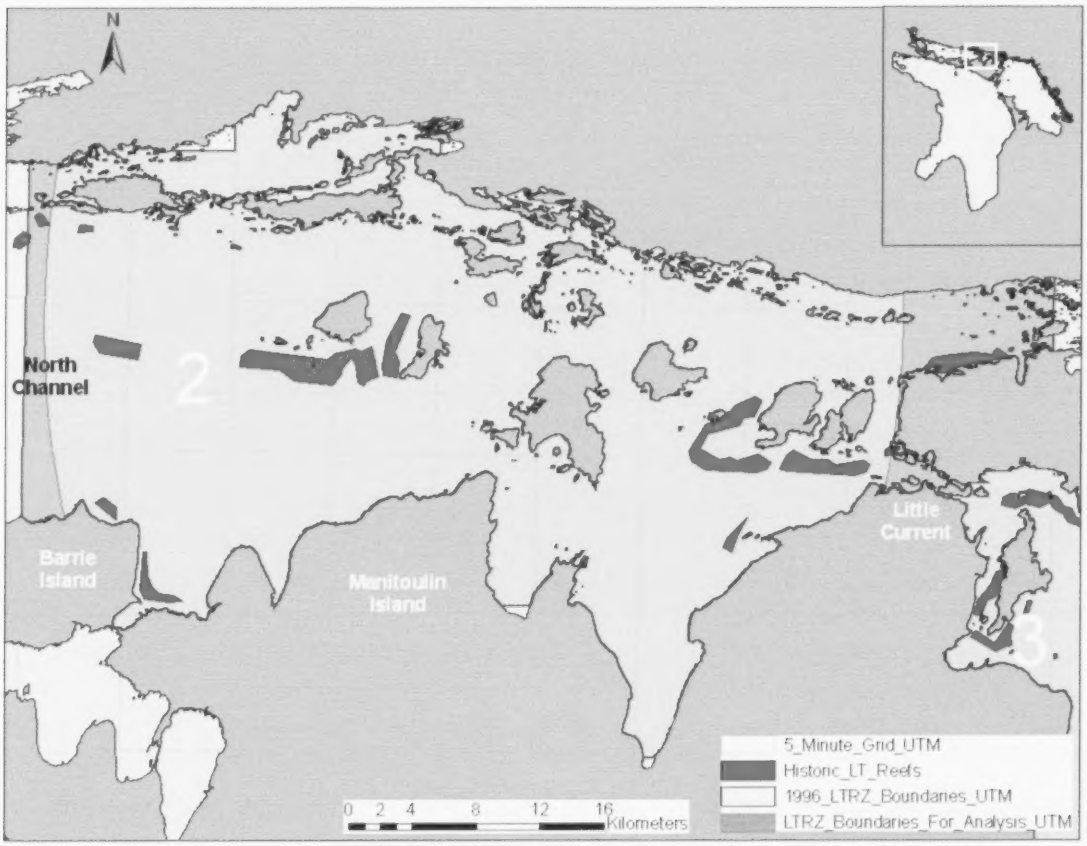
- Increase sampling from the commercial catch
- Continue to closely monitor sea lamprey marking rates

- Develop a rehabilitation strategy (including a stocking plan) for this LTRZ in anticipation of a reduction in sea lamprey abundance, including a change in designation to an active LTRZ
- Consider using Seneca strain lake trout for stocking in this LTRZ

Lake Trout Rehabilitation Zone 2

Lake Trout Rehabilitation Zone 2 is located in the eastern end of the North Channel, and extends from Barrie Island, east to Little Current. It includes all of the waters from the north shore of the North Channel to Manitoulin Island (Figure 6). While waters deeper than 35m are limited, there is extensive shoreline and shoal spawning habitat.

Figure 6. The location of LTRZ 2, its boundaries according to the 1996 Lake Trout Rehabilitation Plan for Lake Huron (Canadian jurisdiction) (beige), the area assessed for this review (both beige and dark grey), and lake trout spawning shoals.



LTRZ 2 was identified in the 1996 Plan as an active zone with secondary protection classification, providing the opportunity for additional regulatory controls on exploitation.

The commercial fishery in LTRZ 2 targets lake whitefish, as well as walleye and yellow perch (*Perca flavescens*). In recent years, gillnets have been used exclusively by commercial fishers in this LTRZ; however live capture gear has been used in this zone historically. Commercial fishing activity is excluded from the eastern third of the zone. Recreational fisheries focus on near shore species such as walleye and northern pike (*Esox lucius)*, although in recent years, fisheries for Chinook salmon, rainbow trout (*Oncorhynchus mykiss*), and lake trout have developed.

Stocking in LTRZ 2 began in 1984 with initial plantings of backcross lake trout. Backcross were replaced with pure strain lake trout in starting in 1992. Stocking strains and rates have varied considerably in this LTRZ, but have averaged over 2.0 yearlings per ha since 2000. The stocking target of 2.5 yearlings per ha, identified in the 1996 Plan, has only been achieved in this LTRZ in two years since 1993 (1998 and 2000). A variety of strains have been stocked in this LTRZ including backcross lake trout, Iroquois Bay, Lake Manitou, Michipicoten Island, Seneca Lake, and Parry Sound. Since 2001 Parry Sound and Iroquois Bay strain lake trout have been stocked from shore in one location in the western portion of the zone as part of a paired plant experiment.

Stocking of coded wire tagged fish in this LTRZ began in 2001. Most of the these fish have been recovered in the North Channel, although a few fish from the 2001 planting were also recovered in southern Georgian Bay. Only one CWT has been recovered in this LTRZ from fish stocked in other parts of the lake (southern Georgian Bay).

Abundance of lake trout in this LTRZ has been variable, but has generally been increasing over the past 10 to 15 years. Despite, the increasing trend, lake trout CPUE in the commercial fishery in LTRZ 2 is one of the lowest in Lake Huron.

Samples from the commercial catch show that almost all fish are clipped (approximately 94% between 1997 and 2006). The age composition has typically been dominated by four, five and six year old fish. It is only in the last few years that any fish older than six years of age have been observed, although they continue to represent a very small proportion of the lake trout population.

Relatively small sample sizes have made it difficult to estimate mortality on an annual basis but using data combined over the past 10 years suggests that mortality has been close to 70%, much higher than the upper threshold considered realistic for re-building lake trout populations. The high mortality estimate is consistent with the truncated age distribution of lake trout in this LTRZ.

Sea lamprey marking rates are consistently very high in this LTRZ; the average from 1997 to 2006 was 27.0 marks per 100 fish. This is similar to the rest of the North Channel and is almost four times higher than the rest of the lake over the same time period.

Current Status

Stocking rates have stabilized somewhat since 1998 but are still below the target of 2.5 yearlings per ha. There is evidence of only a modest lake trout population in this LTRZ. Overall abundance has increased slightly over the past 10-15 years, but not at the rate expected given the number of lake trout stocked in this area. The truncated age distribution suggests that total annual mortality on adult lake trout is excessive; precluding the establishment of a sufficiently large, mature spawning stock. LTRZ 2 has not yet achieved the short term rehabilitation objective.

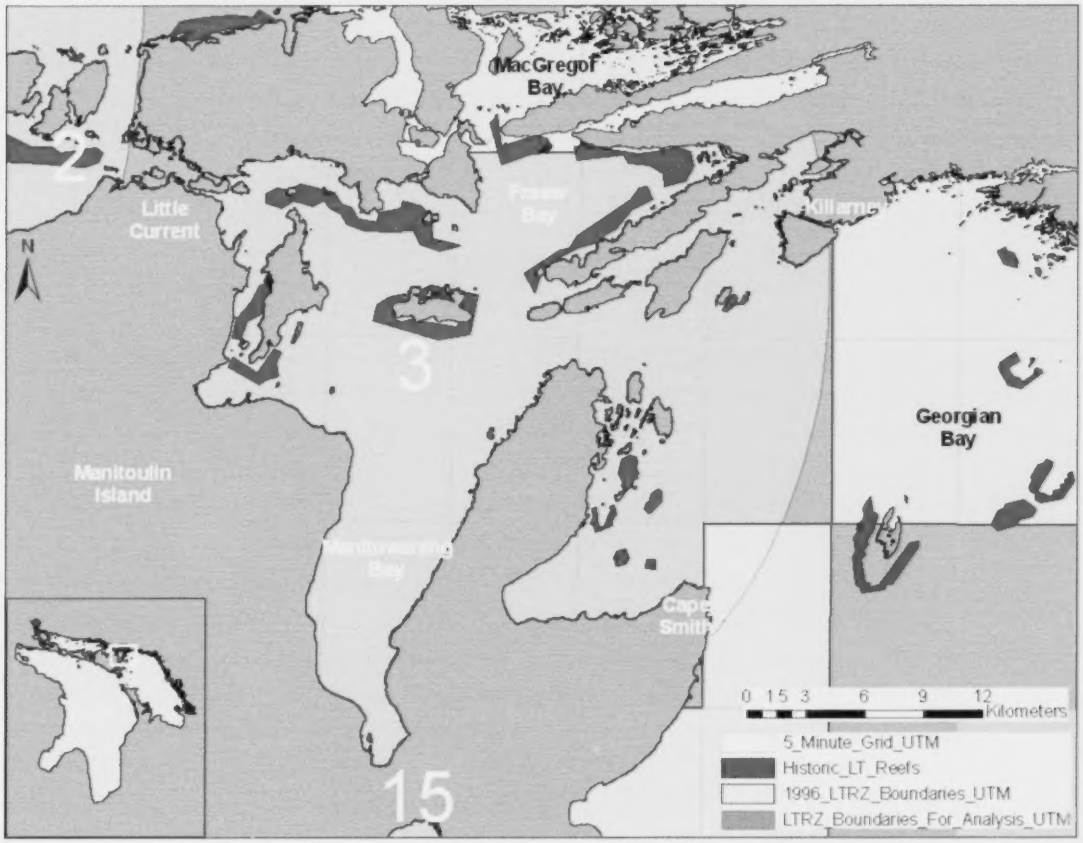
Recommendations

- Continue to monitor lamprey marking rates
- Stabilize stocking rates and strains in this LTRZ to meet the 2.5 yearlings/ha target
- Continue the paired plant experiment; however stock fish within the eastern portion of the zone where commercial fishing is excluded
- Increase commercial and independent sampling in order to increase recoveries of CWTs for use in paired plant analysis
- Encourage the use of live capture gear in this LTRZ by the commercial fishery

Lake Trout Rehabilitation Zone 3

Lake Trout Rehabilitation Zone 3 is located in the northwest corner of Georgian Bay. It includes Manitowaning Bay, Fraser Bay and the waters of Georgian Bay between Cape Smith and Killarney (Figure 7). The area contains several historic lake trout spawning shoals, along with numerous islands and extensive shoreline spawning habitat. Although deeper water is limited within this LTRZ, deepwater habitat is available to the east in Georgian Bay.

Figure 7. The location of LTRZ 3, its boundaries according to the 1996 Lake Trout Rehabilitation Plan for Lake Huron (Canadian jurisdiction) (beige), the area assessed for this review (both beige and dark grey), and lake trout spawning shoals.



LTRZ 3 was identified in the 1996 Plan as an active zone with secondary protection classification, providing the opportunity for additional regulatory controls on exploitation.

A relatively small commercial fishery currently operates in this zone targeting lake whitefish, round whitefish (*Coregonus cylindraceum*), as well as some yellow perch and walleye. Recreational fisheries target lake trout, smallmouth bass (*Micropterus dolomieu*), and northern pike, with winter fisheries targeting lake trout and lake herring.

Stocking in this LTRZ began with splake in 1971 and continued with splake and backcross to 1994. Pure strain lake trout, primarily Lake Manitou strain, were stocked from 1992 to 2001. Since 2002, all of the lake trout stocked in this LTRZ have been Iroquois Bay strain. Stocking rates of pure strain lake trout have been relatively constant in recent years averaging 3.4 yearlings per ha since 1996, exceeding the stocking target of 2.5 yearlings per ha, identified in the 1996 Plan. Approximately 20, 000 lake trout with CWTs have been stocked in this LTRZ since 2003.

Lake trout population data for this LTRZ are limited. There is some information available from the commercial fishery and onboard catch sampling, as well as an independent assessment project that was conducted in the fall of 2004.

The commercial fishery in this zone is irregular, which makes it difficult to assess and quantify. Despite the sporadic fishing effort, lake trout CPUE increased steadily between 1999 and 2004, peaking at 62.8 kg/km of gill net. Lake trout CPUE dropped off sharply in 2005 and 2006. The CPUE of lake trout in commercial fishing effort in LTRZ 3 is high relative to other LTRZs around the lake. Similarly, the incidental catch of lake trout reported in lake whitefish fishing efforts increased steadily between the early 1990s and 2004. Like CPUE, the incidental catch of lake trout dropped in 2005 and 2006 to levels that were slightly below the lake wide average.

A limited number of lake trout from the commercial harvest have been sampled annually from this LTRZ. Prior to the mid 1990s, the samples collected from this LTRZ indicated that virtually all of the fish ranged in age from one to seven years of age, with three to five year olds forming the bulk of the catch. Since that time, the number of biological samples has dropped off sharply. Despite the low number of samples, it appears that five and six year old fish continue to be the most common ages in this LTRZ. In recent years, a few older fish (>8 years) have been observed. Total annual mortality estimated using pooled data collected since 1997 was 37.4%, slightly below the upper threshold for rehabilitating lake trout populations (Ebener 1998).

The Fall Lake Trout Index Netting (FLIN) survey conducted in 2004 indicated that a relatively small spawning population of lake trout was present in Fraser Bay. CPUE was low (0.36 fish/hr) compared to other populations in Lake Huron sampled with this protocol. The average age of lake trout was greater than six and most captured fish were mature and in spawning condition. Interestingly, 24% of the lake trout captured in this project were unclipped and presumed wild.

Despite the high proportion of unclipped lake trout observed in the 2004 spawning survey, unclipped fish have been rare in this LTRZ. Since 1994, only 11 unclipped lake trout have been observed in other sampling programs.

Sea lamprey marking rates are relatively low in this LTRZ. The 10 year average from 1996-2006 was 5.1 marks per 100 fish.

Current Status

Stocking has been at or above the target stocking rate since 1995 and has produced what appears to be a growing population in the area. Relative abundance of lake trout has been increasing in

this zone for several years and appears to be higher than many other LTRZs. Total annual mortality and sea lamprey marking rates are low and older, mature individuals appear to be present in the population. The presence of unclipped fish in recent assessment projects indicates that some level of natural reproduction is occurring in Frazer Bay. While more fishery independent information is needed, it appears that this LTRZ may be approaching the short term rehabilitation objective.

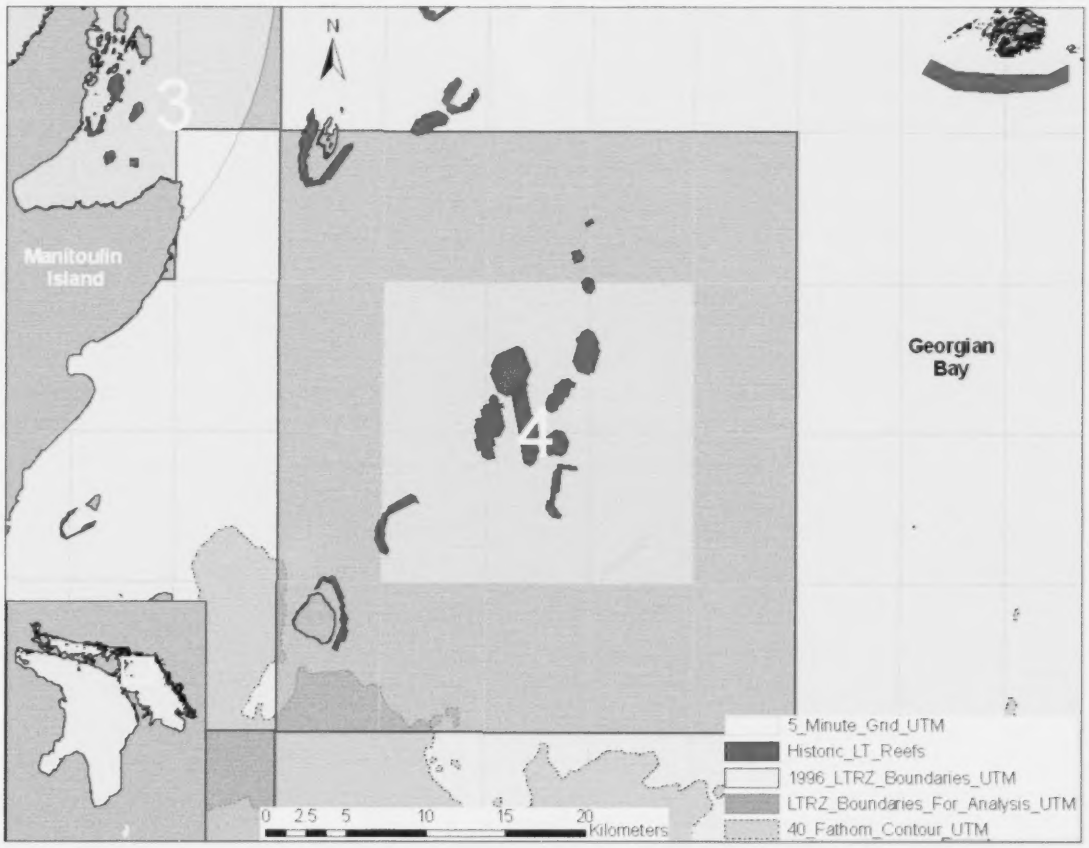
Recommendations

- Increase sampling of the commercial catch in this LTRZ
- Implement additional independent assessment of lake trout in this LTRZ

Lake Trout Rehabilitation Zone 4

The Grand Bank/Dawson Rock LTRZ is located in northern Georgian Bay and is currently the only legislated fish sanctuary in Canadian waters of Lake Huron protecting lake trout spawning habitat. This LTRZ encompasses spawning shoals, numerous reefs and small islands surrounded by extensive deepwater habitat. The sanctuary itself is 36,060 ha (Figure 8).

Figure 8. The location of LTRZ 4, its boundaries according to the 1996 Lake Trout Rehabilitation Plan for Lake Huron (Canadian jurisdiction) (beige), the area assessed for this review (both beige and dark grey), lake trout spawning shoals, and the 40 fathom contour.



LTRZ 4 was identified in the 1996 Plan as an active zone with a primary protection class.

While no fishing is allowed within the sanctuary, small commercial fisheries do exist in the surrounding waters. These target mainly lake whitefish and deepwater chub (*Coregonus hoyi*). There is minimal recreational fishing in the area surrounding this sanctuary given the distance from suitable harbours.

All stocking in this LTRZ has been conducted since 1988 using pure strain lake trout yearlings. Due to the remoteness of this LTRZ, there have been a number of years where stocking was incomplete or did not occur within the zone boundaries. This zone was originally identified for

pulse stocking but logistical considerations favoured yearly stocking events. The Michipicoten strain has been used exclusively since 1993, although both Lake Manitou and Slate Island strains were stocked in this LTRZ prior to 1993. Stocking rates have been extremely variable through time, averaging 2.0 yearlings per ha. While concerted efforts are made to stock fish within the boundaries of the LTRZ, relatively few of the stocking events have occurred on the spawning shoals on Grand Bank proper.

Fish with CWTs were first stocked in this LTRZ in 2003. Two fish with CWTs have been recovered from waters surrounding this LTRZ in 1987 and 2003. Both of these fish were stocked in LTRZ 10 in southwestern Georgian Bay (Figure 2). None of the lake trout with CWTs originally stocked in this LTRZ have been recovered yet.

With no commercial fishing activity in this LTRZ, there is little information to evaluate rehabilitation progress. However, commercial harvests of lake trout in waters surrounding the LTRZ increased substantially after 1995. Harvest from two surrounding commercial fisheries management areas has since dropped to approximately half of the peak harvest levels.

Biological samples from this LTRZ are rare. There were four commercial sampling trips targeting deepwater chub in the immediate vicinity of this LTRZ between 1995 and 1997. A total of 43 lake trout were observed, only one of which was unclipped.

In 2006, an offshore index program was conducted by UGLMU to assess the status of lake trout in this LTRZ. Despite setting 11 index gill nets, only five lake trout were caught and sampled in the project, suggesting that the abundance of lake trout in this LTRZ is extremely low. All of the lake trout were clipped and were either six or seven years of age.

Current Status

Unfortunately, the lack of information makes it difficult to assess the current status of rehabilitation in this zone. Given the number of years that stocking has occurred and the stocking rates that have been employed, a substantial lake trout population would be expected in this LTRZ. However, based upon available data it does not appear that the first objective of rehabilitation has been achieved.

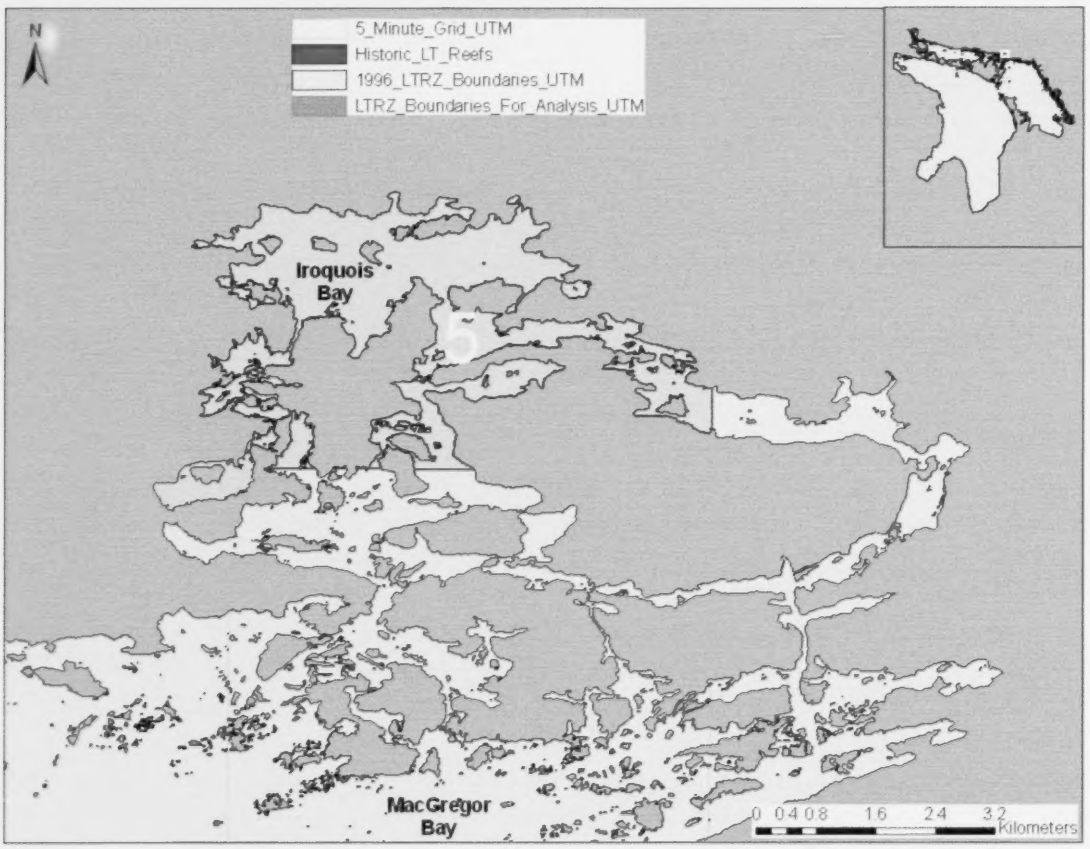
Recommendations

- Continue current stocking strategy ensuring that stocking events occur within LTRZ boundaries over suitable spawning habitat
- Conduct independent assessments in this LTRZ to determine whether a spawning stock exists.

Lake Trout Rehabilitation Zone 5

Lake Trout Rehabilitation Zone 5, Iroquois Bay, is one of two LTRZs in Lake Huron with a remnant lake trout stock. It is located in the extreme northwest corner of Georgian Bay and is isolated from the contiguous waters of the North Channel and northern Georgian Bay (Figure 9). This secluded bay is characterized by several near shore spawning shoals and deep offshore habitat. The total area of LTRZ is only 496 ha.

Figure 9. The location of LTRZ 5, its boundaries according to the 1996 Lake Trout Rehabilitation Plan for Lake Huron (Canadian jurisdiction) (beige) and the area assessed for this review (both beige and dark grey).



LTRZ 5 was identified in the 1996 Plan as an active zone with secondary protection class.

No commercial fishery exists in Iroquois Bay although First Nation subsistence fishing has occurred sporadically in the past. Iroquois Bay supports recreational fisheries during open water and winter periods, traditionally targeting lake trout, muskellunge (*Esox masquinongy*), and smallmouth bass (*Micropterus dolomieux*).

It is speculated that water quality impacts from Sudbury basin mining and smelting activities may have caused recruitment failure in the past due to acidification of egg incubation and nursery habitats as was observed with walleye in this area (Olver et al. 1982).

Stocking in this LTRZ has almost always been done with Iroquois Bay strain lake trout. However, small numbers of backcross were captured in assessment programs conducted in 1994 and 1996 indicating movement of stocked backcross into this LTRZ; presumably from nearby Frazer Bay. Until 1988, wild lake trout egg collections were used for stocking; however since then yearlings from Iroquois Bay origin hatchery brood stock have been used. Since 1995, stocking densities have been high, averaging more than 7.5 yearlings per ha.

A small number of lake trout with CWTs were stocked in this LTRZ in 2003. To date, no CWTs have ever been recovered in LTRZ 5 and movements into or out of this zone are currently unknown but are expected to be minimal given the isolated nature of Iroquois Bay.

Yield from Iroquois Bay was calculated using estimates of harvest from summer recreational fisheries. In 1995 the estimated harvest and yield of lake trout was 763 kg or 1.53 kg per ha. In 2000, a similar survey suggested that summer yield had dropped to only 483 kg or 0.97 kg per ha. While it appears that yield declined between 1995 and 2000, the yield in 2000 was still over 3 times the rate recommended by Reid et al. (2001) for rehabilitating lake trout populations. Despite the relatively high yield, the estimated CPUE from creel surveys actually increased, suggesting that lake trout abundance in this LTRZ may have been increasing over the same time period.

CPUE observed using short set gill nets on the spawning shoals has been highly variable ranging from 0.6 fish /km to 3.4 fish /km. The lowest CPUE was observed in the last survey conducted in 2002. The very low value in 2002 would suggest that abundance of spawning aged lake trout may be declining.

FLIN surveys conducted in 2002 and 2004 had mean catch rates of 1.44 and 1.56 fish/hour, respectively. These catch rates are similar to CPUE's from other LTRZs using this protocol. Unlike data collected in Parry Sound FLIN surveys, the catch in this LTRZ was mostly juvenile, stocked lake trout. Only 16% of the lake trout catch was unclipped, and presumably wild.

Data collected from both independent surveys and the recreational fishery in LTRZ 5 show a declining trend in mean size and age.

Sea lamprey wounding rates are quite low in this LTRZ. The average from 1992-1999 was 1.9 marks per 100 fish. There were no fish caught with sea lamprey wounds or scars in the 2002 or 2004 FLIN surveys.

Current Status

This LTRZ has been stocked at densities higher than any other LTRZ. Independent surveys suggest that survival of stocked fish is high, however an adult population, comprised of either stocked or wild fish, does not appear to be building. Spawning surveys indicate that only small numbers of large, old fish are present in the spawning population. The continued presence of small numbers of wild fish in FLIN catches suggests that natural reproduction is taking place, although these fish do not appear to be contributing to any degree to the spawning population.

Relatively high yields of lake trout in recreational fisheries may be imposing excessive mortality on adult and sub-adult lake trout. These high yields are occurring in spite of this LTRZ having the most restrictive recreational fishing regulations for lake trout in the basin since 1999.

Unfortunately, it does not appear that LTRZ 5 has achieved the short term rehabilitation objective (OMNR 1996).

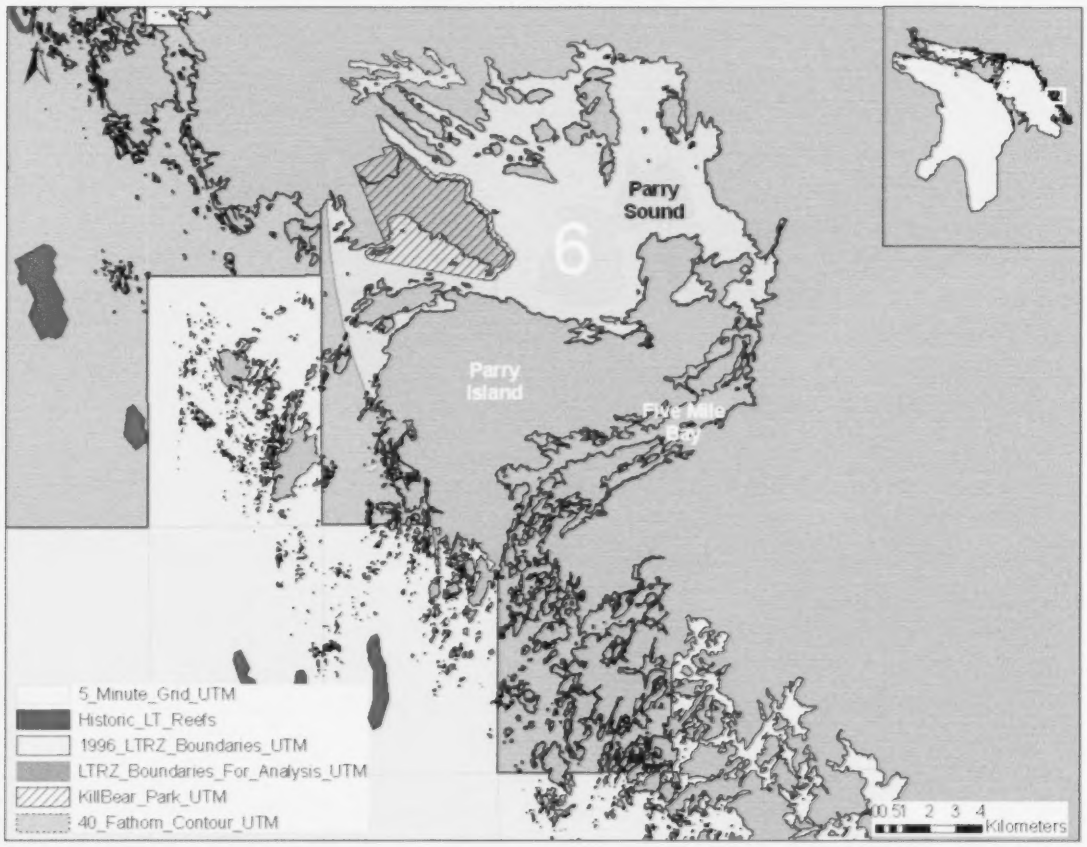
Recommendations

- Examine the potential for a complete closure of the recreational fishery in this LTRZ to reduce fishing mortality
- Reduce stocking rates by 50% as natural reproduction has been observed and stocking rates are well above the target density
- Monitor for natural reproduction on a regular basis
- Research why stocked fish are not recruiting to the spawning population

Lake Trout Rehabilitation Zone 6

Lake Trout Rehabilitation Zone 6 is located in eastern Georgian Bay. It includes Parry Sound and the waters out to the western point of Parry Island (Figure 10) and is characterized by numerous spawning shoals and adjacent deepwater habitat. Like Iroquois Bay, Parry Sound supports one of only two remnant Great Lakes lake trout populations outside of Lake Superior.

Figure 10. The location of LTRZ 6, its boundaries according to the 1996 Lake Trout Rehabilitation Plan for Lake Huron (Canadian jurisdiction) (beige), the area assessed for this review (both beige and dark grey), the 40 fathom contour, and the location of Killbear Provincial Park.



LTRZ 6 was identified in the 1996 Plan as an active zone with secondary protection class. Due to the presence of the remnant lake trout stock, a suite of restrictive regulations have been implemented in this zone. These include a sanctuary in the waters adjacent to Killbear Provincial Park, and restrictive seasons and bag limits both in the waters of Parry Sound proper and Georgian Bay in the vicinity of Parry Sound (Reid et al 2001). Commercial fishing is not allowed in Parry Sound proper.

A small commercial fishery operated just outside of Parry Sound up to 2003. This fishery targeted mainly lake whitefish and deepwater chub. Recreational fisheries exist in Parry Sound targeting lake trout, rainbow trout, smallmouth bass and northern pike.

Parry Sound was stocked with Parry Sound strain lake trout beginning in 1981. Backcross were also stocked in this LTRZ but these stocking events were terminated in 1991 and all stocking was terminated in Parry Sound proper in 1998 due to the prevalence of wild lake trout in assessment surveys. Since that time, the only stocking that has occurred in the area has been in Five Mile Bay, to the south of Parry Sound. This stocking has been conducted to restore a lake trout population in Five Mile Bay, which did not recover with the population in Parry Sound proper.

From 1981 to 1997 stocking rates in Parry Sound proper, including backcross and splake, averaged more than 9 yearlings per ha. However, if only pure strain lake trout are considered, then the stocking density dropped to an average of 4.5 yearlings per ha during the same period, as presented in Reid et al (2001). This stocking density is over the recommended stocking rate of 2.5 yearlings per ha.

A small number of fish with CWTs have been included in the recent stocking in Five Mile Bay. To date, the only recovery of these fish has occurred in southern Georgian Bay. However, adults sampled during spawning surveys in Parry Sound proper have been tagged with t-bar anchor tags for several years. Twenty two of these fish have been recaptured outside of Parry Sound, but still within 20 km of the LTRZ. The recovery pattern of both CWTs and anchor tags suggests that there is some movement of fish out of Parry Sound into adjacent waters of Georgian Bay. It is unknown if this movement of tagged lake trout outside Parry Sound is permanent or temporary.

Fall trap netting projects conducted through the 1990s suggested that abundance of spawning lake trout in Parry Sound was relatively high. Mean annual CPUE typically ranged from 12 to 14 fish per net-night. Similarly, in fall littoral index netting (FLIN) surveys conducted between 1998 and 2001 the average catch of lake trout was 1.37 fish/hr, almost four times higher than the mean CPUE observed in LTRZ 3 using the same protocol. The FLIN surveys in Parry Sound also caught several wild juvenile lake trout, confirming that natural reproduction is occurring in LTRZ 6.

Along with overall CPUE, the proportion of unclipped lake trout in the fall trap net catches increased throughout the 1990s. Between the mid 1990s and 2006, the average proportion of unclipped fish in the catch rose from less than 50% to more than 90%. A similar increase was observed in the catch from the commercial fishery outside of Parry Sound where the proportion of unclipped fish rose to 56% during the same time period. This rise in natural reproduction facilitated the cessation of stocking and implementation of restrictive fishing regulations within Parry Sound. The lower proportion of unclipped fish outside of Parry Sound is largely attributable to the continued stocking in the vicinity of the Limestone Islands (LTRZ 7).

The mean age of lake trout observed in the spawning surveys and commercial catch samples has steadily increased over the past 10 years from 7.5 in 1996 to 9.9 in 2005. The mean age to maturity for lake trout (both genders combined) in this LTRZ was 5.9 years while the mean age of mature females observed in spawning surveys was 7.9 years, suggesting that a well developed, mature spawning population exists in this LTRZ.

Total annual mortality estimated using catch curves from pooled data suggested that mortality declined from an average of close to 50% in the mid to late 1990s to only 35% since 2000.

Sea lamprey wounding rates have typically been very low in Parry Sound, often less than 0.5 marks per 100 fish, suggesting that natural and fishing mortality are the principal components of total annual morality rates in this LTRZ. However, in 2005 and 2006, the number of wounds observed on Parry Sound lake trout jumped to 23.1 and 15.9 wounds per 100 fish.

Current Status

Lake trout rehabilitation in this LTRZ has occurred with the long term objective met, as documented in Reid et al. (2001). Fishery controls continue to be relatively restrictive to protect and enhance the rehabilitated lake trout population. Evidence of movement into the surrounding waters of Georgian Bay suggests that lake trout from Parry Sound are expanding their range.

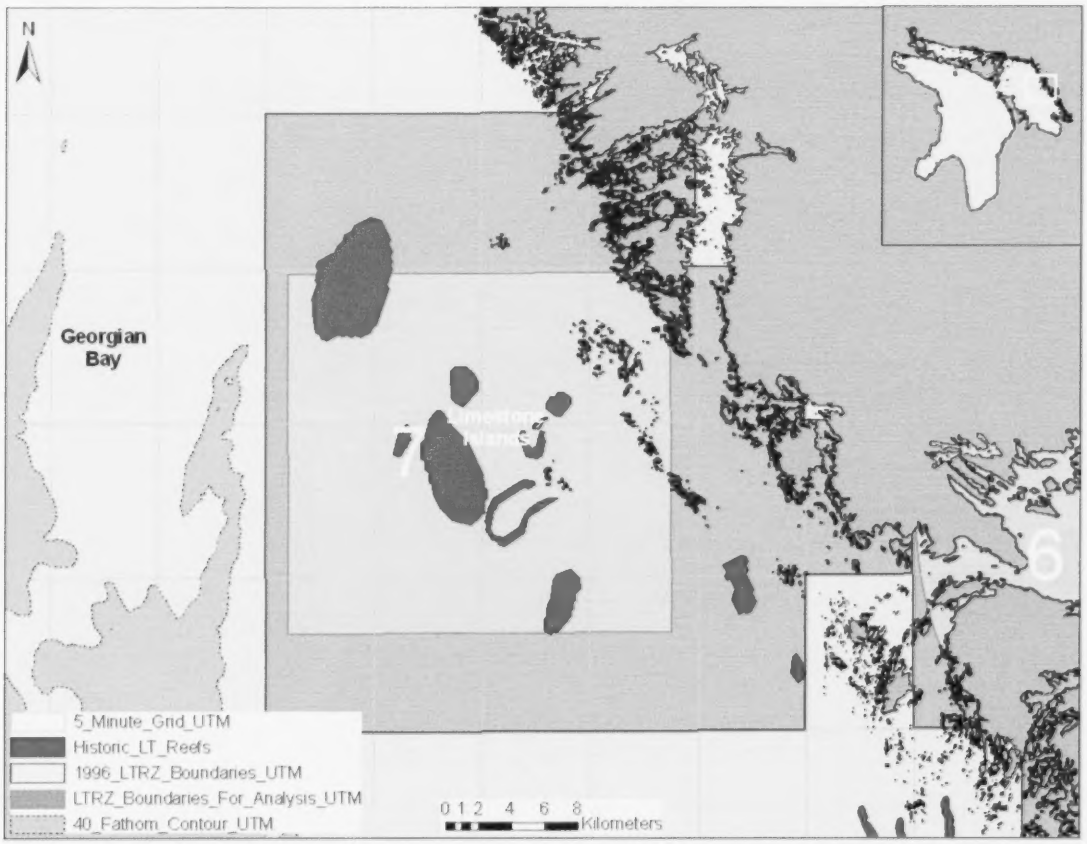
Recommendations

- Continue to monitor on a regular basis to ensure that controls on exploitation are adequate
- Continue to monitor sea lamprey wounding rates given recent increases in wounding
- Rehabilitation strategies used in Parry Sound should be replicated in other locations.

Lake Trout Rehabilitation Zone 7

Lake Trout Rehabilitation Zone 7 is located in eastern Georgian Bay and encompasses the Limestone Islands to the northwest of Parry Sound (Figure 11). The area is comprised of several islands, reefs and shoals and includes abundant spawning, nursery and summer habitat for lake trout.

Figure 11. The location of LTRZ 7, its boundaries according to the 1996 Lake Trout Rehabilitation Plan for Lake Huron (Canadian jurisdiction) (beige), the area assessed for this review (both beige and dark grey), lake trout spawning shoals, and the 40 fathom contour.



LTRZ 7 was identified in the 1996 Plan as an active zone with a primary protection class. This LTRZ was to be given sanctuary status but it was never formally established as a sanctuary.

A small commercial fishery that operated in portions of this LTRZ was retired in 2003. Recreational fisheries exist in the near-shore waters for lake trout, northern pike, and walleye. More recently, small Chinook salmon fisheries have developed in both near and offshore areas of this LTRZ.

The Limestone Islands were stocked on two separate occasions in the early 1990s with Lake Superior strains. In 1996 this LTRZ was chosen to be part of a pulse stocking experiment which

entailed a cycle of three years of intense stocking followed by a three year stocking hiatus. The first cycle was completed between 1997 and 1999 while the second cycle was conducted from 2003 to 2005. All of the pulse stocking has utilized Parry Sound strain yearlings. The average stocking densities during these two cycles were 5.0 and 2.6 yearlings per ha, respectively. However, uncertainty does exist as to whether stocked fish have been placed close enough to spawning habitat for homing to occur.

Fish with CWTs were first stocked in this LTRZ in 2003, and to date, no CWTs have been recovered in any sampling conducted in this zone. Thirteen lake trout with external tags have been reported from commercial catches in this LTRZ; all were originally tagged in Parry Sound.

Lake trout first appeared in the commercial harvest in 1994 and catches increased steadily to 2002. However, since that time, catches have dropped off substantially. Similarly, the incidental catch of lake trout in lake whitefish gillnets increased steadily after 1995 and by 2000, lake trout out numbered whitefish in commercial efforts. This trend continued up to 2004, when almost two kilograms of lake trout where reported for each harvested kilogram of lake whitefish. This was reflected in the reported commercial CPUE for lake trout which increased from 24.9 kg/km prior to 2000 to 114.4 kg/km after. These increases coincide with the intensive stocking conducted between 1997 and 1999.

Most of the biological data available for this LTRZ is from commercial catch sampling conducted up to 2003, although a spring survey was conducted in the vicinity of the Limestone Islands in 2006 using standard index gill nets. A small commercial fishery that operated in this LTRZ was retired in 2003 and as a result, no commercial catch data have been available since then. The observed age distribution of the catch in these data was strongly influenced by the earliest pulse stocking events, suggesting that survival of the stocked fish was high. Since 1998, fish older than eight years of age have been regularly observed in this LTRZ. Total annual mortality estimated using all available data from 1997 to 2006 was 36.3% per year, below the maximum target mortality rate of 40%.

Unclipped fish have been observed in this LTRZ, but the proportion has been highly variable over time, ranging from 0 to 35%. In the most recent years, more than 20% of the fish sampled have been unclipped. However, it is unclear if these fish were produced in LTRZ 7 or have migrated from neighbouring LTRZs where lake trout rehabilitation is well underway (i.e. – Parry Sound).

The catch of lake trout in the 2006 spring survey was low (only 3.6 lake trout per index net), suggesting that abundance in the immediate vicinity of the Limestones is not as high as anticipated given the number of fish stocked in the zone and the CPUE reported from the commercial fishery. The age distribution of the fish that were sampled in this project was broad, with fish up to 15 years of age in the catch. Uncertainty around stocking locations, dispersal to spring habitats and prey concentrations, and homing may have influenced these netting results.

Sea lamprey marking rates observed in this LTRZ are typically low, averaging 3.3 wounds per 100 fish between 1997 and 2006.

Current Status

Lake Trout Rehabilitation Zone 7 has not yet achieved the short term rehabilitation objective. Survival of fish stocked in the first pulse period was high and resulted in increasing abundance of four to six year old lake trout between 1998 and 2003. Additionally, total annual mortality appeared to be relatively low, and as a result, larger, older fish were regularly encountered in this LTRZ. However, low catches in the 2006 spring survey suggest that abundance has dropped in recent years, and there is little evidence of recruitment from the most recent stocking events.

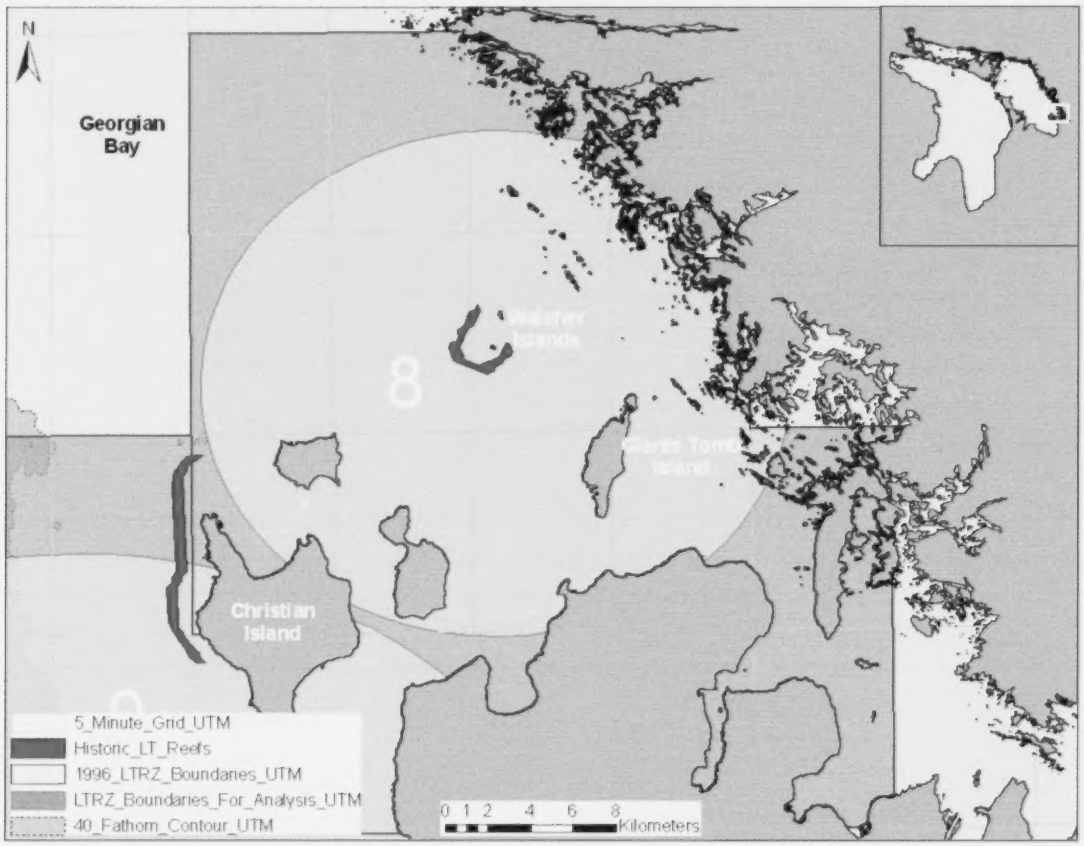
Recommendations

- Establish sanctuary status for the zone
- Continue the pulse experiment for at least 3 full cycles
- Continue to conduct independent assessments in this LTRZ to determine whether a spawning stock exists.
- Ensure that fish are stocked directly on the best available spawning habitat in the LTRZ (i.e. the Limestone reefs)

Lake Trout Rehabilitation Zone 8

Lake Trout Rehabilitation Zone 8 is located in the southeast corner of Georgian Bay and is focused around the Watcher Island complex (Figure 12). The Watcher Island complex (the Watchers) is characterized by an abundance of lake trout spawning habitat with near-by deepwater habitat.

Figure 12. The location of LTRZ 8, its boundaries according to the 1996 Lake Trout Rehabilitation Plan for Lake Huron (Canadian jurisdiction) (beige), the area assessed for this review (both beige and dark grey), lake trout spawning shoals, and the 40 fathom contour.



LTRZ 8 was identified in the 1996 Plan as an active zone with secondary protection class.

A commercial fishery exists in the area, targeting primarily lake whitefish, with some harvest of deepwater chub, walleye, and yellow perch. Recently, lake trout have become a large component of the commercial harvest. Recreational fisheries in the area focus on near shore species such as walleye, northern pike, and smallmouth bass. Fisheries for lake trout and Chinook salmon have also developed in offshore regions of this LTRZ.

The Watchers were stocked with Slate Island strain lake trout in 1993 and 1996. In 1996 this LTRZ was identified as a candidate location for pulse stocking. The pulse stocking would entail

a cycle of three years of intense stocking followed by a three year stocking hiatus. The first stocking cycle on the Watchers was completed between 2000 and 2002 using Parry Sound strain yearlings. The average stocking density during this cycle was 5.0 fish per ha. The second pulse stocking cycle was started in 2006, when Parry Sound yearlings were stocked at a density of 6.9 yearlings per ha. Unfortunately, a large proportion of the fish stocked in this LTRZ have not been stocked directly on the shoals surrounding the Watcher Islands, but have been shore stocked from a number of locations between Giants Tomb and Christian Islands.

Almost 120 000 yearlings with CWTs were stocked in this LTRZ in 1993. Most of the recoveries from this stocking event have occurred in this zone; although a substantial proportion (29%) were also recovered in LTRZ 9, immediately to the west. Lake trout with CWTs that were originally stocked in other LTRZs have also been recovered in this zone. The original stocking locations of these fish include Owen Sound and the Bruce Archipelago. More recently, approximately 43 000 lake trout with CWTs were included in the 2006 stocking activities. To date, no fish from this stocking event have been recovered.

Due to the early stage of rehabilitation in this LTRZ, no independent assessment for lake trout has taken place. The only information available for this LTRZ is from the commercial fishery. Lake trout catches in the commercial fishery began to increase in 1995 in response to early stocking in the area. Harvest of lake trout in this area, also within the boundaries of Quota Management Area (QMA) 5-7, rose sharply between 2002 and 2005, peaking at more than 36 000 kg. Harvest in 2006 dropped to less than one third of those levels. This rise in harvest was also reflected in the incidental catch of lake trout from the commercial fishery while targeting other species such as whitefish. Since 2003, more lake trout have been reported in commercial efforts than lake whitefish, and the incidental catch rate (ICR) while targeting other species continues to be among the highest on Lake Huron.

The age composition and size of lake trout sampled from this zone have been strongly influenced by the pulse stocking. After 2002, the 1999 and subsequently the 2002 year classes dominated the catch. Despite the high ICR in commercial catches and high lake trout harvest, fish older than eight years of age continue to be sampled from this LTRZ (although in low numbers). Total annual mortality estimated from the age composition data since 2001 was 62.7%, much higher than the upper mortality threshold of 40% for rehabilitating lake trout populations (Ebener 1998).

Sea lamprey marking rates have typically been low in this LTRZ, ranging from 0 to 4.4 wounds/100 fish between 1998 and 2003. However, wounding rates jumped in 2004, averaging more then 9 wounds/100 fish since that time.

Current Status

This LTRZ has not yet achieved the short term rehabilitation objective. While some lake trout have survived from early stockings prior to 1996, those stocking rates were likely too low to establish a sufficiently large spawning stock. The first three-year cycle of intense stocking was completed by 2002. Catch and harvest reported from the commercial fishery demonstrated that abundance has increased dramatically following these stocking events. However, fishing

mortality will continue to be a key factor in determining how many of the stocked lake trout survive to maturity in this LTRZ.

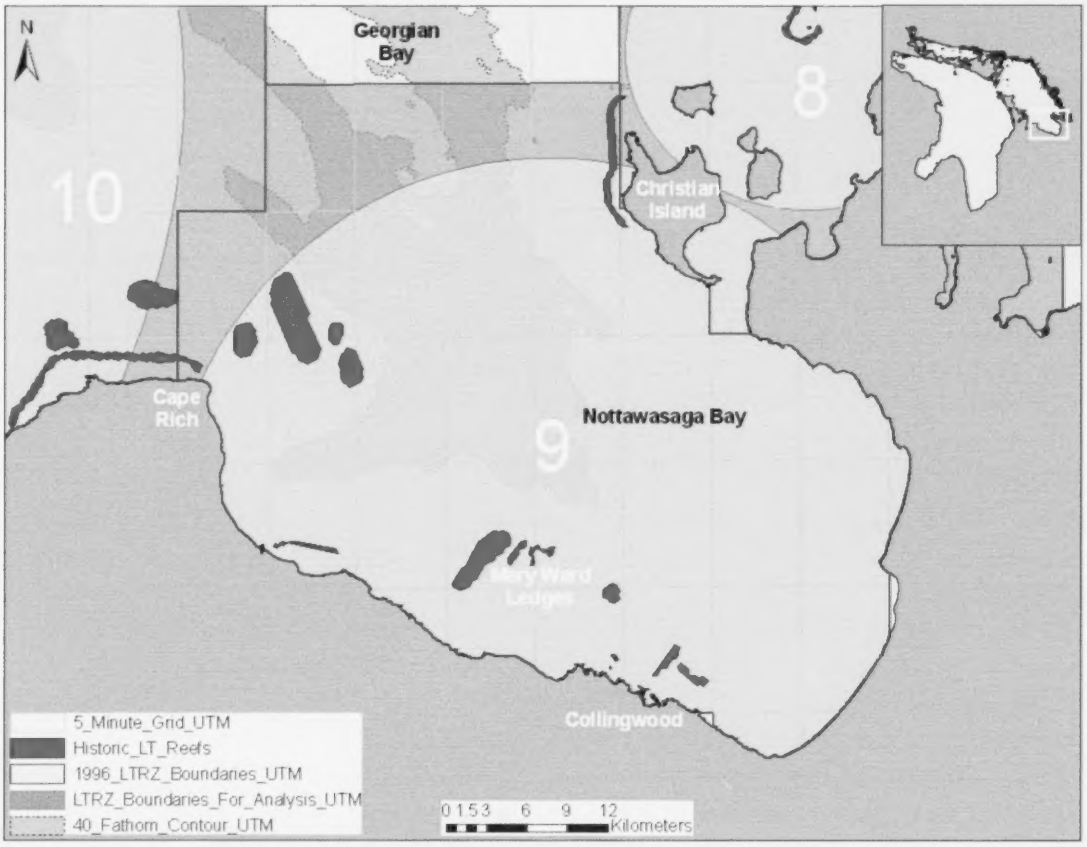
Recommendations

- Control commercial exploitation of lake trout such that mortality rates are kept below 40%
- Continue the current pulse stocking experiment for at least 3 complete cycles ensuring that fish are stocked on the best available habitat (i.e. the shoals surrounding the Watcher Island complex)
- Conduct an independent assessment of lake trout in this LTRZ

Lake Trout Rehabilitation Zone 9

Lake Trout Rehabilitation Zone 9 encompasses all of Nottawasaga Bay from Christian Island in the east to Cape Rich in the west (Figure 13). The area contains several near shore spawning shoals, including the Mary Ward Ledges, a large series of reefs and shoals. Deepwater habitat is found in the central and western areas of the zone.

Figure 13. The location of LTRZ 9, its boundaries according to the 1996 Lake Trout Rehabilitation Plan for Lake Huron (Canadian jurisdiction) (beige), the area assessed for this review (both beige and dark grey), lake trout spawning shoals, and the 40 fathom contour.



LTRZ 9 was identified in the 1996 Plan as an active zone with secondary protection class.

The largest commercial fishery in Georgian Bay is found within Nottawasaga Bay. Commercial effort traditionally targets lake whitefish and deepwater chub. Recreational fisheries target non-native salmonids and lake trout, as well as smallmouth bass in nearshore areas.

This LTRZ has a long history of stocking beginning in 1968. Prior to 1993 stocking was comprised of splake and backcross. Pure strain lake trout stocking started in 1993 with an average of approximately 282 000 yearlings stocked annually between 1996 and 2006. The overall stocking rate since 2000 has averaged 2.9 yearlings per ha, just over the target rate of 2.5

yearlings per ha. Since 1999, the majority of the stocking in this LTRZ has been with Parry Sound and Seneca strain lake trout as part of a paired plant experiment, although substantial numbers of Slate Island yearlings continue to be stocked as well. In recent years the majority of the fish stocked in this LTRZ have been stocked near Cape Rich.

A large number of lake trout have been stocked in this LTRZ with CWTs. Between 1996 and 2006, an average of 97 000 yearling lake trout with CWTs have been stocked annually in this LTRZ. Most of the recoveries from these stocking events have occurred in this zone (76.7%), suggesting very little emigration from south eastern Georgian Bay. It should be noted these CWT return rates are not standardized and that the absence of index netting and limited commercial catch sampling in adjacent LTRZs may underestimate the rate of dispersal from this LTRZ. Lake trout with CWTs that were originally stocked in other LTRZs have also been recovered in this zone, including large numbers from LTRZ 10 (southwestern Georgian Bay) as well the Bruce Archipelago (LTRZ 13) and the North Channel.

Commercial harvest, onboard catch sampling, and independent netting data for the past 15 years all show that the relative abundance of pure strain lake trout peaked in 1999. Since 1999, index netting data indicate that relative abundance has dropped substantially in this LTRZ. The mean CPUE for lake trout in index nets in 1999 was 34.3 fish per net. By 2006, the mean had dropped to only 1.3 lake trout per net. Commercial harvest of lake trout from this LTRZ has been increasing steadily since the early 1990s, with noticeable spikes in 1996, 2004 and again in 2006.

The size of lake trout in both the commercial catch and independent assessment appears to be increasing. Similarly, the mean age of lake trout in this LTRZ is also increasing, especially since 2004. Unfortunately, the increase in both mean size and mean age in recent years appears to be attributable to an absence of smaller, younger fish rather than the establishment of a mature spawning stock. The mean age of females continues to be close to the mean age at maturity, suggesting that mortality on the adult proportion of the population continues to be high.

The age distribution of lake trout from this zone is typically dominated by four to six year old fish. Although fish older than eight years of age have been sampled in this LTRZ, they typically make up less than 2% of the fish sampled in any given year. The absence of older fish is reflected in the estimated total annual mortality which typically ranges from 45 to 60% per year.

Wild or unclipped fish are rare in this LTRZ. The proportion of unclipped fish ranged from 0% to 6.3% from all assessment programs conducted in this LTRZ. The long term average for all years between 1990 and 2006 was only 1.9%. The low proportion of unclipped fish in the catch clearly shows that there is little or no natural reproduction taking place in this zone.

Sea lamprey marking rates are generally low in this LTRZ. The average marking rate from 1994 to 2002 was 1.8 marks per 100 fish, although the marking rate almost doubled between 2003 and 2006 to 3.2 marks per 100 fish.

Current Status

LTRZ 9 has yet to attain the short term objective of establishing a sufficiently large spawning stock. Stocking rates have been above the rehabilitation target for most years when pure strain lake trout were stocked. Although short term survival of stocked fish was high during the 1990s, the mean age of the population continued to be low and the age distribution was clearly truncated indicating that adult mortality was excessive. In recent years, the age distribution continues to be truncated, but the absence of young fish in index gear suggests that the survival of fish from the most recent stocking events may be lower than in the past.

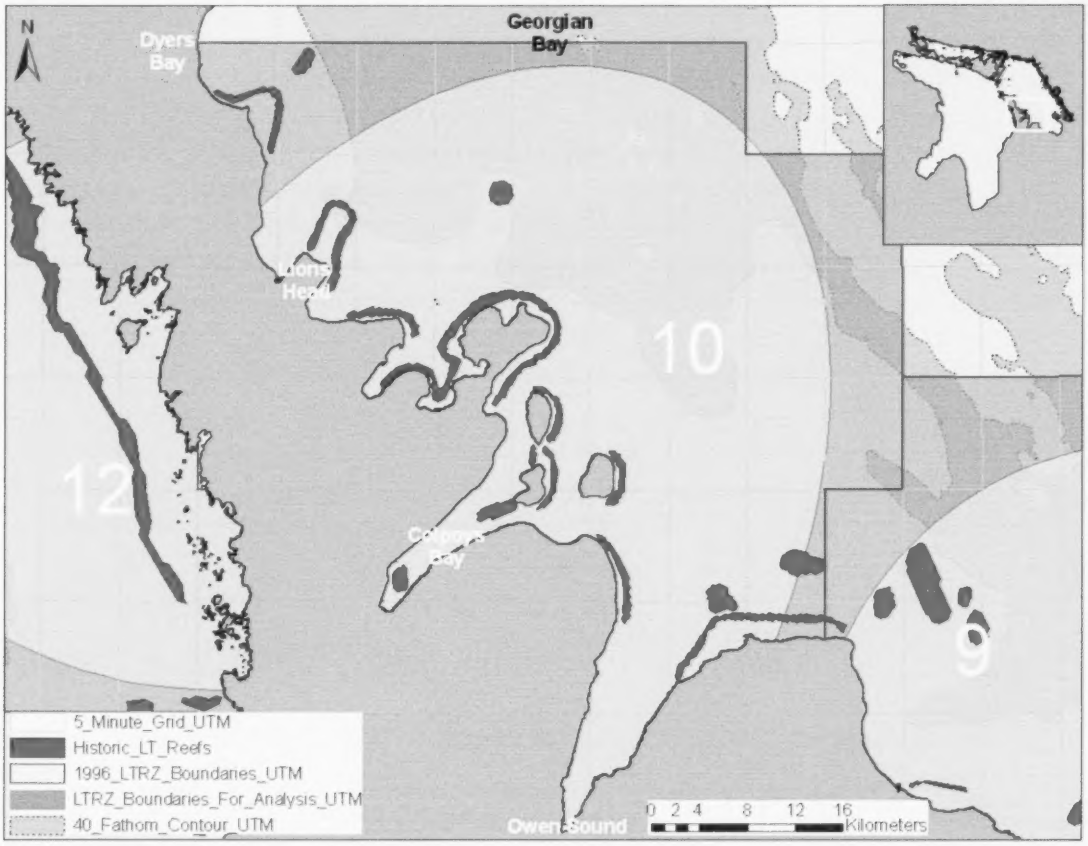
Recommendations

- Stock fish on the Mary Ward Ledges to maximize imprinting on the best spawning habitat in the LTRZ
- Stop the stocking of Slate Island strain lake trout in this LTRZ
- Control commercial harvest in order to keep mortality on older fish under 40%
- Continue independent assessment to monitor the status of lake trout in this LTRZ.
- Analyze data from this LTRZ as part of the paired plant experiment to determine which stocking strain most successfully promotes rehabilitation
- Use this analysis of strains to direct future stocking practises in an effort to further rehabilitation efforts in this LTRZ

Lake Trout Rehabilitation Zone 10

Lake Trout Rehabilitation Zone 10 is located in southwestern Georgian Bay (Figure 14). This zone contains several historical lake trout spawning locations, most of which are near shore, although offshore reefs and islands also provide spawning habitat. This zone has abundant deepwater habitat.

Figure 14. The location of LTRZ 10, its boundaries according to the 1996 Lake Trout Rehabilitation Plan for Lake Huron (Canadian jurisdiction) (beige), the area assessed for this review (both beige and dark grey), lake trout spawning shoals, and the 40 fathom contour.



LTRZ 10 was identified in the 1996 Plan as an active zone with secondary protection class.

A commercial fishery exists in this LTRZ which primarily targets lake whitefish, lake trout and deepwater chub. Prior to 1994, commercial fishing activity in the zone was limited. Since 1994, commercial activity has increased dramatically, although fishing normally occurs outside of Owen Sound and Colpoys Bays. A large recreational salmonid fishery exists within this LTRZ, primarily targeting non-native salmonids, although lake trout are also harvested. A fairly active winter recreational fishery for lake whitefish exists when conditions permit. Lake trout are also harvested during this time.

This LTRZ has a long history of stocking. Prior to 1987, splake and backcross were stocked throughout the zone. By 1992 splake and backcross were phased out, resulting in exclusive stocking of pure strain lake trout. Most of these fish have been Lake Manitou and Slate Island strain yearlings, although small numbers of Parry Sound, Seneca and Michipicoten strain yearlings have also been stocked in recent years. Average stocking rates between 1992 and 1999 were 1.8 fish per ha but have increased to 2.6 fish per ha after 2000.

Approximately 1.5 million fish with CWTs have been stocked in this LTRZ since 1986. Most of the CWTs that were originally stocked in LTRZ 10 have been recovered in LTRZ 9 immediately to the east. This is likely reflective of the larger fishery in LTRZ 9 and greater probability for capture as a result. Small numbers of lake trout with CWTs originally stocked in LTRZ 10 have also been recovered in the Bruce Archipelago (LTRZ 13), the North Channel, Grand Bank (LTRZ 4) and the Watcher Island complex (LTRZ 8). Fish stocked in other LTRZs and subsequently recaptured in LTRZ 10 are generally rare, although fish stocked in the main basin, the Bruce Archipelago, Parry Sound (LTRZ 6) and southern Georgian Bay (LTRZ 9) have also been recovered from LTRZ 10. The overall pattern of CWT recoveries suggest that lake trout move freely between LTRZ 9 and 10, with relatively few individuals moving into or out of southern Georgian Bay.

The relative abundance of lake trout in this LTRZ has been difficult to assess because the independent assessment time series are discontinuous. The mean catch of lake trout in the Owen Sound offshore index program rose steadily from 1986 to 1992, after which it plateaued at approximately 20 fish per net until the termination of the program in 1997. A fall trap netting survey in Owen Sound Bay started in 1996 and ran annually until 2005. CPUE values in this survey were typically in the range of 20- to 30 fish per net lift, although a substantial drop was evident in both 2004 and 2005. The drop in the relative abundance of spawners was also reflected in the catch of lake trout in short set gill nets set throughout Owen Sound between 2003 and 2005. Over this time period, the mean catch of lake trout dropped from 8.0 to 2.5 fish per net.

The age composition of lake trout sampled from this LTRZ has typically been dominated by four, five and six year old fish. Fish older than 8 years of age tend to be rare, typically less than 8% of the population, even during spawning surveys. Total annual mortality estimated from catch curves using data collected between 2000 and 2006 was 49%, higher than the lake trout rehabilitation threshold of 40%. The chronically truncated age distribution suggests that mortality on the adult proportion of the population may be considerably higher. This is further supported by the extremely low tag return rate from the fall spawning surveys. 2,780 lake trout have been uniquely tagged and released in this LTRZ since 1999. Less than four percent of these fish have been recovered on subsequent spawning surveys.

However, the proportion of unclipped fish in this LTRZ has been higher than many parts of the lake, especially during fall spawning surveys. Since 2000, 20% of the fish sampled have been unclipped (429 of 2120), and in some years this proportion approached one third of all fish sampled. The proportion of unclipped fish in gill netting conducted in Owen Sound in the spring of 2006 was very low (<3% or the total catch), but the small size of the unclipped lake trout

(<300 mm total length) suggests that some natural reproduction is continuing to occur in this LTRZ.

Lamprey wounding in this LTRZ was generally low prior to 2002, averaging 2.6 wounds per 100 fish between 1996 and 2002. Since that time however, the frequency of lamprey wounds has increased steadily, averaging 9.5 wounds per 100 fish. This wounding rate is almost 2 times higher than the GLCF target of 5.0 wounds or less per 100 fish.

Current Status

Stocking densities since 2000 in this LTRZ should have been adequate to establish a spawning population. Although it is uncertain if a large spawning stock currently exists in this LTRZ, the presence of unclipped fish in the adult population would suggest that at least some natural reproduction has occurred in the past decade. However, the truncated age distribution indicates that excessive adult mortality may be impeding lake trout rehabilitation and it appears that a sufficiently large, mature spawning stock may no longer exist in this zone.

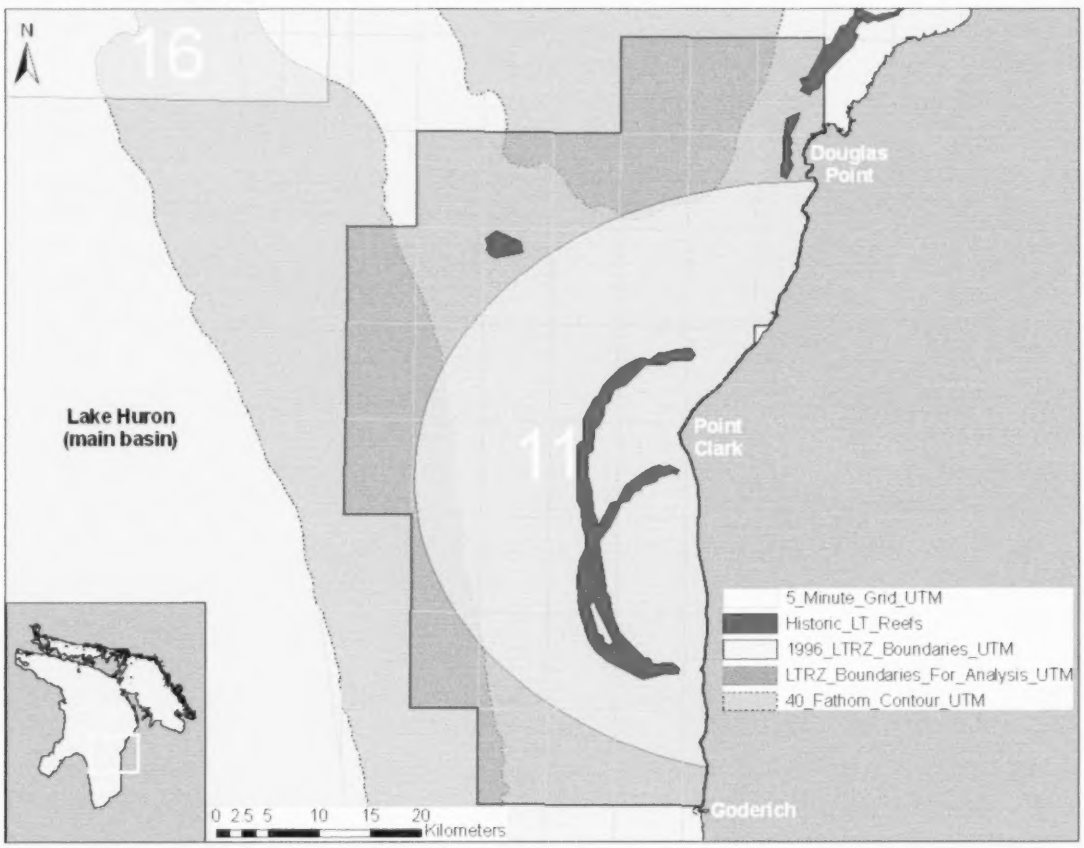
Recommendations

- Control exploitation to reduce total annual mortality to 40% or less and increase representation of fish older than age 6 in the population
- Continue independent assessment of the population

Lake Trout Rehabilitation Zone 11

Lake Trout Rehabilitation Zone 11 is located in the south-central region of the main basin of Lake Huron and is centered on Point Clark (Figure 15). Point Clark is the eastern connection of an underwater geological feature called the Six Fathom Scarp that stretches across Lake Huron from Thunder Bay, Michigan. The area has two large offshore reefs that have been identified as historical lake trout spawning sites. Although data are scarce, Point Clark was generally considered the most southerly lake trout spawning location in Ontario waters of the main basin. Deepwater habitat is readily available.

Figure 15. The location of LTRZ 11, its boundaries according to the 1996 Lake Trout Rehabilitation Plan for Lake Huron (Canadian jurisdiction) (beige), the area assessed for this review (both beige and dark grey), lake trout spawning shoals, and the 40 fathom contour.



LTRZ 11 was identified in the 1996 Plan as an active zone with a secondary protection class.

A large commercial fishery exists immediately to the south of Point Clark. This fishery has expanded since 1994 in response to increased lake whitefish abundance in southern Lake Huron. A recreational fishery also operates in this LTRZ, targeting non-native salmonids and more recently lake trout. Some nearshore fishing also targets smallmouth bass and yellow perch.

This LTRZ was originally identified in the 1996 Plan (OMNR 1996) as a potential candidate for pulse stocking (a cycle of three years of intense stocking followed by a three year stocking hiatus). Slate Island strain yearlings were available on a yearly basis however, and have been stocked annually since 1993. The average stocking density prior to 2000 was 2.1 yearlings per ha, although densities have averaged only 1.4 yearlings per ha since 2000.

Prior to 2001, no lake trout with CWTs were stocked in this LTRZ. Since 2002, an average of approximately 50 000 lake trout with CWTs have been released annually in this LTRZ. Large numbers of lake trout stocked in U.S. waters of the main basin are also coded wire tagged and many have subsequently been recovered in LTRZ 11. Since 1988, 496 CWTs have been recovered from lake trout caught in this zone. Most of these fish were originally stocked by the United States Fish and Wildlife Service (USFWS) on Six Fathom Bank (56%), although large numbers were stocked at other locations on the U.S. side of the main basin. A small number of lake trout originally stocked in Georgian Bay and even Lake Michigan have also been recovered in this LTRZ, although these instances tend to be rare (i.e. less than 3% of all recoveries). To date, only one lake trout stocked with a CWT by the MNR in this LTRZ has been recovered within the boundaries of LTRZ 11. This pattern of recoveries may suggest that the 6-Fathom Scarp serves as a geological underwater bridge connecting lake trout populations of the east shore, mid-lake, and west shore of the Central Main Basin of Lake Huron.

No independent lake trout assessments have been conducted in this LTRZ although annual assessment programs are conducted in the waters to the north and south of Point Clark. These assessment programs show increasing lake trout CPUE beginning in the mid 1990s and continuing to present. Similarly, CPUE from commercial harvest reported in the vicinity of this LTRZ has been increasing over the same time period.

The rate of incidentally caught lake trout observed in the commercial fishery peaked in 2002 at 0.34 lake trout for every lake whitefish in LTRZ 11. This is consistent with the lake wide incidental catch of lake trout which peaked at 0.28 trout for every lake whitefish in 2003. Since 2002, the ICR has averaged 0.24 in LTRZ 11. While the ICR value is relatively low when compared to other LTRZs around the lake, the size of the lake whitefish fishery and the associated gill net effort deployed in the vicinity of this LTRZ results in substantial lake trout harvest.

The age distribution of lake trout sampled from this LTRZ has shown a noticeable shift towards older fish in recent years. Between 1995 and 2001, the age distribution was characterized by four, five and six year old fish, with relatively few older fish. Since 2002, the age distribution is generally composed of five to eight year old fish with fish as old as 19 being sampled. However, fish younger than four years of age are now absent from the samples. Mortality estimates calculated from data pooled from 1994 to 2001 and 2002 to 2006 suggest that total annual mortality in this LTRZ has actually dropped in recent years from 48% to 41%. Paradoxically, the lower mortality rate is at least partially attributable to the absence of four year olds in the catch in recent years.

Although the age composition of lake trout captured in LTRZ 11 is shifting towards older individuals, the mean age of mature females in commercial and assessment data sets remained

similar to the age to maturity. This suggests the number of older individuals is small and that little progress has been made in establishing a mature spawning stock of lake trout in this LTRZ. To date, very few unclipped fish have been documented in this LTRZ.

Sea lamprey marking rates averaged 2.5 wounds per 100 fish from 1993 to 2002, but increased substantially between 2003 and 2006, averaging 10.4 wounds per 100 fish. The GLFC target for lamprey wounding rates for Lake Huron is a maximum of 5.0 wounds per 100 fish.

Current Status

Although stocking in this zone has generally been below target densities, immigration of lake trout into this LTRZ from U.S. waters is substantial. The relative abundance of lake trout has been increasing in recent years and the age distribution has shifted towards an older, more mature population. Despite the shift in the age distribution, there is still little evidence of natural reproduction in this LTRZ.

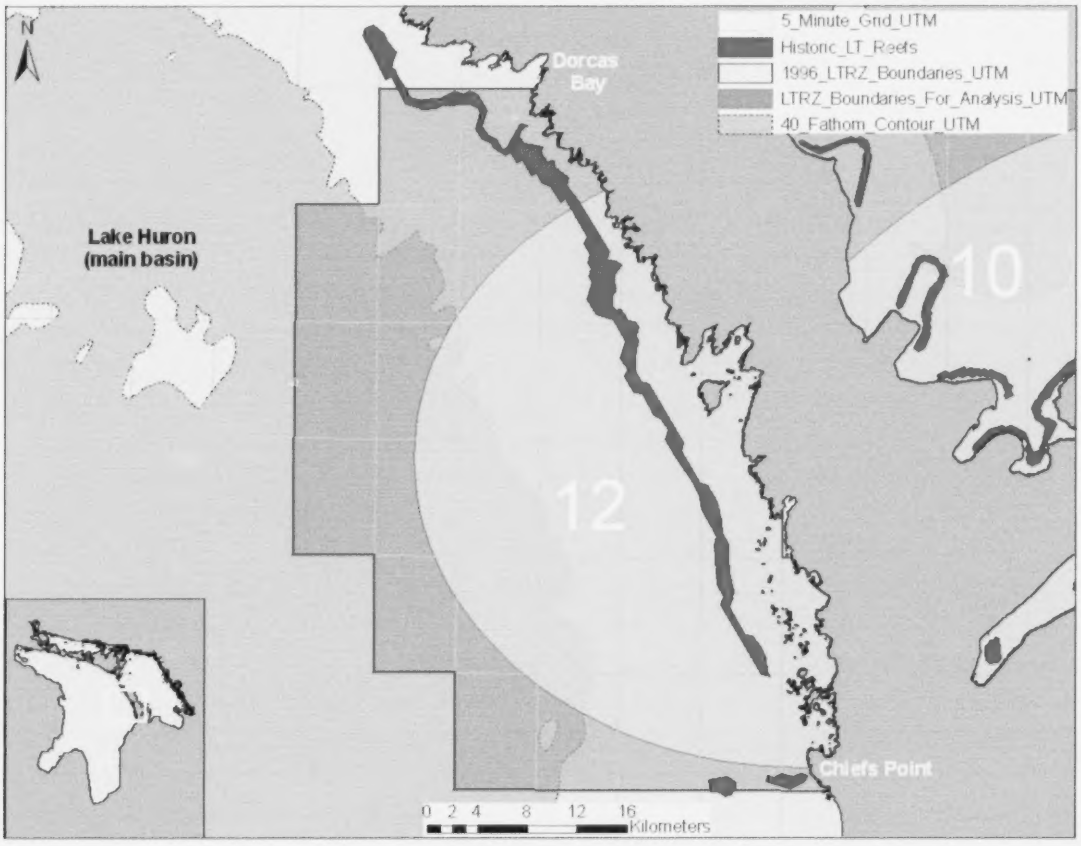
Recommendations

- Control sources of adult mortality and maintain adult mortality below 40%
- Continue the use of CWTs in this LTRZ
- Increase biological samples from the commercial fishery in southern Lake Huron
- Conduct an independent index program to collect fishery independent estimates of relative abundance, population structure, age distribution, and evaluate the presence of unclipped fish in this LTRZ

Lake Trout Rehabilitation Zone 12

Lake Trout Rehabilitation Zone 12 encompasses the western shores of the Bruce Peninsula from Chiefs Point north to Dorcas Bay (Figure 16). This area includes the Fishing Islands, a stretch of small islands, reefs and shoals which provide abundant lake trout spawning habitat close to the deepwater habitat of the main basin.

Figure 16. The location of LTRZ 12, its boundaries according to the 1996 Lake Trout Rehabilitation Plan for Lake Huron (Canadian jurisdiction) (beige), the area assessed for this review (both beige and dark grey), lake trout spawning shoals, and the 40 fathom contour.



This LTRZ was identified in the 1996 lake trout rehabilitation plan as a deferred rehabilitation zone. This designation reflects the active, large mesh gill net fishery operating in the area. Given the rehabilitation status, the protection class was designated as tertiary.

A substantial commercial fishery exists in this LTRZ. While the dynamics of the fishery changed between 1990 and 2000, it remains relatively large, targeting primarily lake whitefish, with limited fishing for deepwater chub and walleye. Recreational fisheries, focused mostly on non-native salmonids, have also developed over the past 20 to 25 years in the vicinity of this LTRZ.

Lake trout rehabilitation in this LTRZ was deferred, in part due to the difficulties associated with re-establishing lake trout in an area with a relatively large commercial gill net fishery. Consequently, large scale stocking of lake trout has not been initiated. The only *Salvelinus* stocking in LTRZ 12 occurred in 1970 and 1971 when relatively small numbers of splake were stocked.

Data sources for this LTRZ include the reported harvest from the commercial fishery, wholesale fish buyer's records, the OMNR Offshore Index Assessment (OSIA) program, and limited dockside or plant sampling data provided by the Nawash First Nation Fisheries Office. Historical, onboard commercial catch sampling data are also available for this LTRZ up to 1999, although the number of samples dropped substantially after 1995.

Although lake trout have never been stocked in LTRZ 12, the abundance of lake trout is relatively high, and has increased steadily since the early 1990s. This increase in abundance has been reflected in both the commercial harvest and the OMNR's index netting program. Between 1994 and 2001, the estimated annual harvest of lake trout from LTRZ 12 rose from 7 670 to 25 895 kg, although harvest has averaged only 14 555 kg per year since then. Most of the harvest is from incidental catch of lake trout in commercial fishing effort targeting lake whitefish. Similar to commercial harvest, the catch of lake trout in MNR index nets rose from 0.67 to over 2.7 fish per net between 1993 and 2003, but has since declined to between 1.2 and 1.8 lake trout per net.

Coded wire tags collected from fish caught in the index program conducted in this LTRZ suggest that the majority (81%) of the 157 CWTs recovered were originally stocked by the USFWS on Six Fathom Bank, approximately 80 km to the west of LTRZ 12. Lake trout originally stocked in the Bruce Archipelago north of Tobermory (LTRZ 13) and several other American stocking locations have also been caught in this LTRZ.

Unfortunately, there is relatively little age information associated with fish sampled from this LTRZ, despite relatively large sample sizes in some years. However, the age data that are available show a distinct shift towards older, more mature fish in recent years. Between 1991 and 1997, the age distribution was characterized by three to six year old fish, with no fish older than eight years of age. In the most recent years (2003-2006), the age distribution has been characterized by fish between five and eight years of age with occasional fish older than ten years of age. During this time period, only one lake trout less than four years of age was sampled.

Catch curves calculated using the available age data pooled between 1991 and 1997 and 2003 to 2006 suggest that total annual mortality has dropped substantially in recent years from more than 70% in the 1990s to 39.9% currently. This drop in mortality is consistent with the broad, mature age distribution observed in recent years.

Although most of the fish sampled from this LTRZ are clipped, an increase in the number of unclipped fish has been observed in recent years. Prior to 1999 few unclipped fish were observed in this LTRZ, but since 2000, the number of unclipped (and potentially wild) fish documented in the offshore index program has risen steadily to a high of 25.0% in 2006. The

proportion of unclipped fish observed in the offshore index program has averaged more than 20% since 2003.

Generally, lamprey wounding in this part of Lake Huron is low. Between 1996 and 2006, the average wounding rate observed in this LTRZ was 5.8 wounds per 100 fish. While this wounding rate is slightly above the GLFC target of no more than 5.0 wounds per 100 fish, the number of wounds observed in QMAs 4-4 and 4-7 (which encompass LTRZ 12) was only 4.0 which suggests that lamprey-induced mortality should not be an impediment to establishing a mature spawning stock in this LTRZ.

Current Status

The consistent occurrence of unclipped juvenile or sub-adult lake trout in offshore index nets in recent years supports the notion that this LTRZ has suitable spawning and rearing habitat, and that rehabilitation may be possible if adult mortality can be controlled. The level of lamprey wounding observed in this LTRZ should not impede the establishment of a hatchery-origin spawning stock. However, the commercial fishery in this LTRZ continues to harvest large numbers of lake trout while targeting lake whitefish using large mesh gill nets.

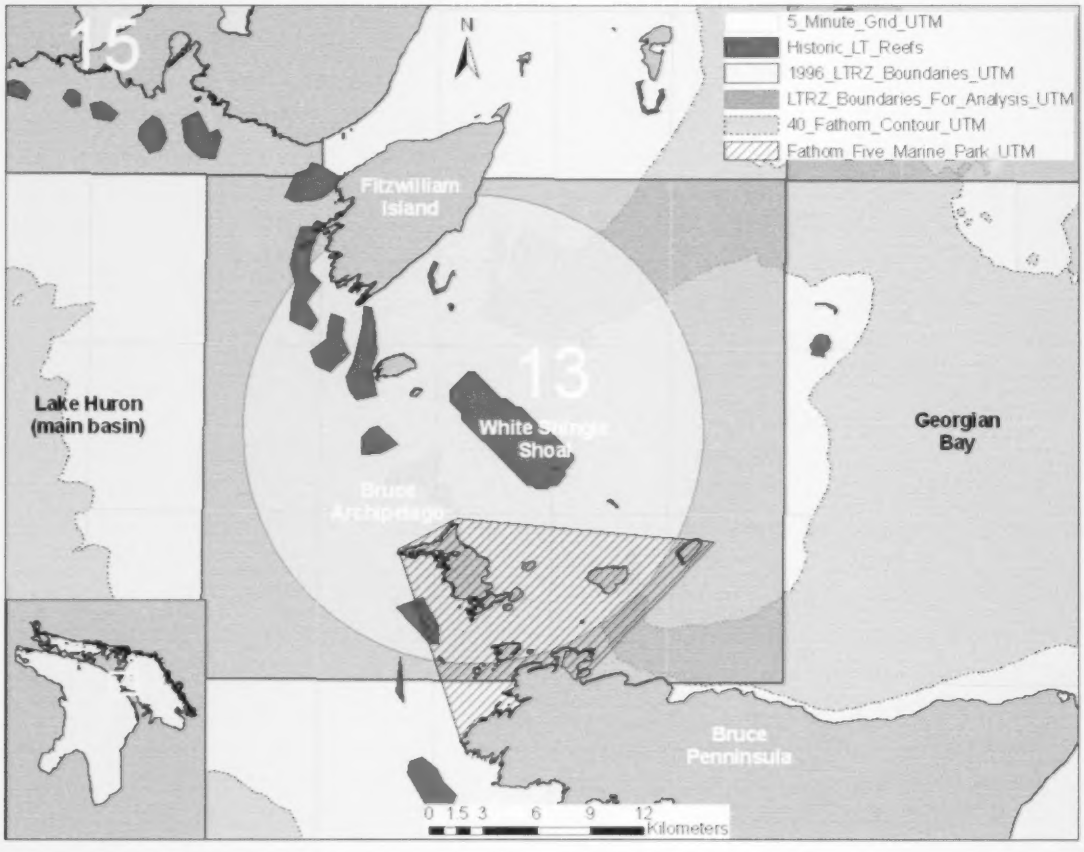
Recommendations

- Maintain the deferred status of this LTRZ given the active, large mesh gill net fishery in this zone
- Continue to monitor the commercial fishery
- Continue the offshore index program to collect fishery independent estimates of relative abundance, population structure and age distribution
- Closely monitor the number of unclipped fish captured in the index program in this LTRZ in the absence of stocking

Lake Trout Rehabilitation Zone 13

Lake Trout Rehabilitation Zone 13 is located in the area that separates the main basin from Georgian Bay, an area known as the Bruce Archipelago. The Bruce Archipelago is the northward extension of the Niagara Escarpment and is characterized by numerous islands, reefs and shoals stretching from the tip of the Bruce Peninsula north to Fitzwilliam Island (Figure 17). The zone contains several historic lake trout spawning locations as well as deepwater habitat in both the main basin and Georgian Bay. Fathom Five National Marine Park is also located in the southern section of this LTRZ.

Figure 17. The location of LTRZ 13, its boundaries according to the 1996 Lake Trout Rehabilitation Plan for Lake Huron (Canadian jurisdiction) (beige), the area assessed for this review (both beige and dark grey), lake trout spawning shoals, the 40 fathom contour, and the location of the Fathom Five National Marine Park.



This LTRZ was identified in the 1996 Plan as an active rehabilitation zone with a secondary protection class designation.

Small commercial and recreational fisheries exist in this LTRZ. Commercial fisheries traditionally targeted deepwater chub in the northern sections of this LTRZ with some limited lake whitefish effort and harvest. Changes in the commercial fishery and the decline of deepwater chub populations have resulted in more lake whitefish effort and harvest in recent

years. Recreational fisheries in the area target non-native salmonids, and to a lesser extent, lake trout.

Several different lake trout strains and life stages have been stocked in the waters of the Bruce Archipelago, with the majority of fish stocked in the southern portions of the LTRZ near Tobermory. Pure strain lake trout stocking began in 1990 with the release of 43 000 Lake Manitou strain yearlings. Subsequent stocking activities have included eyed eggs, fry, spring fingerlings and yearlings of Parry Sound, Lake Manitou and Michipicoten strains. Stocking densities have ranged widely since 1990, but have averaged 3.0 yearlings (or yearling equivalents) since 2000.

Between 1992 and 2006, approximately 300 000 fish with CWTs were included in the stocking activities in this LTRZ. Between 1993 and 2006, 121 of these fish were recovered. Most of these fish (n=65) were recaptured within the Bruce Archipelago, although small numbers have been recovered from other locations around the lake, including central and northern main basin and throughout Georgian Bay. Relatively few fish originally stocked outside of the Bruce Archipelago have been recaptured in this LTRZ. Most of these fish (n=10) were originally stocked by the USFWS on Six Fathom Bank approximately 80 km to the south west, one was originally stocked in the northern main basin, while the remaining fish (n=4) were originally stocked by the OMNR in southern Georgian Bay.

The primary data source for this LTRZ is the reported harvest and effort from the commercial fishery. Unfortunately, there is very little onboard catch sampling information for this LTRZ and the OSIA project conducted in waters near Tobermory targeted predominantly deepwater chub (only 2-3 lake trout were caught each year in this program). Other information sources include data provided by the Nawash Fishery Office and an OMNR research program that was conducted near White Shingle Shoal a number of times between 1993 and 2003.

Commercial harvest of lake trout from this LTRZ was relatively low prior to 1994, averaging only 165 kg per year between 1979 and 1994. Since 1995, however, the lake trout harvest has grown considerably. The average reported harvest from 1995 to 2006 has been 6 292 kg per year. Similarly, indicators of relative abundance suggest that the density of lake trout in this LTRZ is fairly high. CPUE in commercial nets between 1986 and 1994 averaged only 11.4 kg/km. However, CPUE rose sharply afterwards and peaked at 195.3 kg/km in 1997. CPUE for lake trout in the commercial fishery has subsequently declined and has stabilized at approximately 40 kg/km since 1999.

There is relatively little age information available for this LTRZ. When ages were available, the catch was dominated by 3, 4 and 5 year old fish. Fish older than 6 years of age make up less than 5% of the catch. This is reflected in the mean age, which fluctuated without trend between 3.5 and 5.2 years of age. The available maturity data suggest that male lake trout in this LTRZ reach maturity by age 6, but females mature at a much slower rate, failing to reach full maturity by age 8.

Very few unclipped lake trout have been observed in this LTRZ (n=14). Less than 3% of the fish examined were unclipped, and possibly of wild origin. This is despite the fact that large

numbers of lake trout have been stocked in this LTRZ at ages or life stages that prevented fin clipping or other forms of marking.

Lamprey wounding in this LTRZ is very low, averaging 1.1 marks per 100 fish since 1979.

Current Status

Lamprey induced mortality does not appear to be inhibiting lake trout rehabilitation in this LTRZ and the increasing abundance of lake trout in the commercial fishery suggests that the survival of lake trout stocked by conventional means is good. However, the severely truncated age distribution and the lack of mature fish suggest that high mortality rates endured by adult and sub-adult lake trout are preventing this LTRZ from reaching the short term rehabilitation objective. Despite the fact that large numbers of unclipped lake trout have been stocked in this LTRZ (at ages or life stages that preclude marking), unclipped adult lake trout have been virtually absent in subsequent surveys and commercial catch monitoring. This suggests that there may be early life stage issues in this LTRZ such as inadequate rearing habitat, presence of large predator populations, or the lack of appropriate forage for young lake trout.

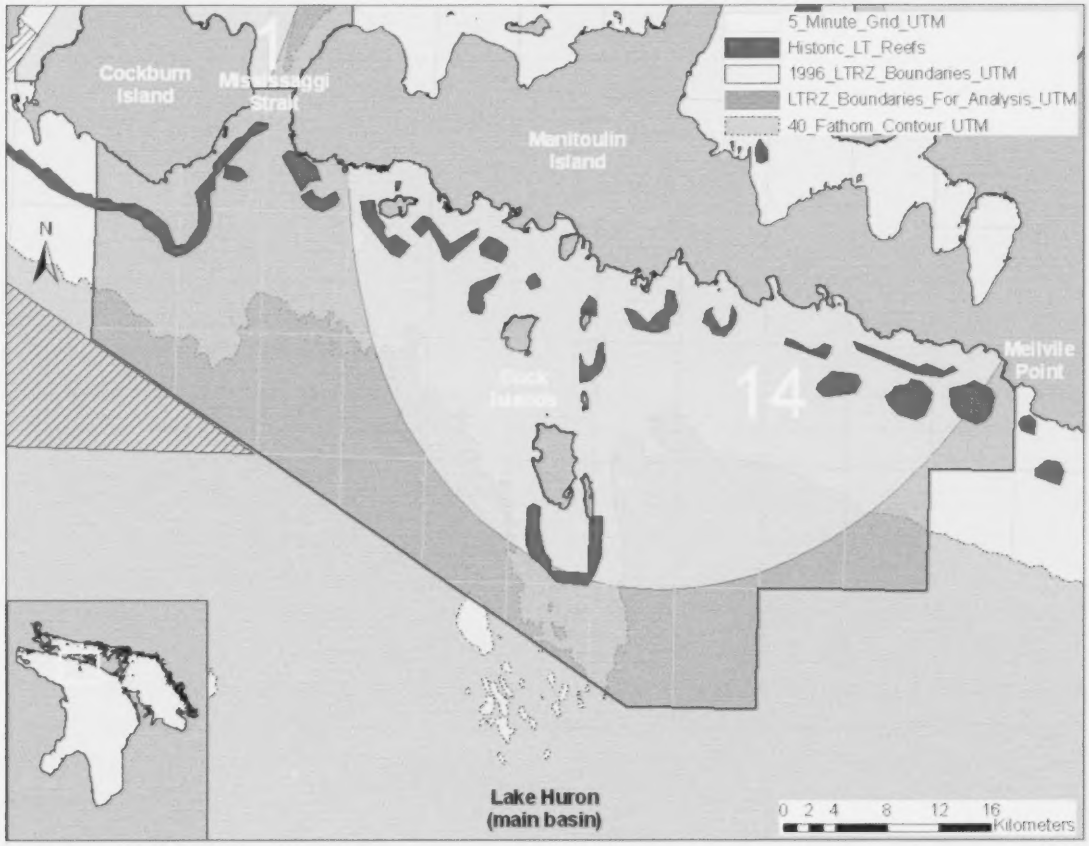
Recommendations

- Control sources of mortality and maintain total annual mortality below 40%
- Increase sampling of commercial catch.
- Implement an index program to collect fishery independent estimates of relative abundance, spawning stock abundance, population structure, age distribution, recover CWTs, and to examine for the presence of unclipped fish.
- Investigate potential impediments to early life history survival
- Stock the majority of the fish in the LTRZ in the northern portions of the zone where spawning habitat is more abundant

Lake Trout Rehabilitation Zone 14

Lake Trout Rehabilitation Zone 14 is located along the southern shore of Manitoulin Island in the main basin of Lake Huron (Figure 18). The LTRZ stretches from Mississaugi Strait eastward to Melville Point. Extensive historical lake trout spawning shoals, abundant reefs and islands, as well as nearshore spawning habitat are all found in this zone. Abundant deepwater habitat is found to the immediate south of this LTRZ.

Figure 18. The location of LTRZ 14, its boundaries according to the 1996 Lake Trout Rehabilitation Plan for Lake Huron (Canadian jurisdiction) (beige), the area assessed for this review (both beige and dark grey), lake trout spawning shoals, and the 40 fathom contour.



LTRZ 14 was identified in the 1996 Plan as a deferred zone due to high sea lamprey abundance and the presence of a large commercial fishery. As such, the zone was assigned a tertiary protection class.

The commercial fishery in this LTRZ, targets mainly lake whitefish, with both gill and trap net gear. A small amount of deepwater chub fishing also occurs in this zone. There is a small recreational fishery in this LTRZ targeting non-native salmonids.

As a deferred zone, LTRZ 14 has not been actively stocked. However, a substantial number of lake trout are caught in this LTRZ every year. Recovered CWTs indicate that many of these fish were stocked by the USFWS in the Drummond Island Refuge, a U.S. sanctuary located immediately to the west of this LTRZ, although fish originally stocked on Six Fathom Bank (LTRZ 16) and the Grand Bank (LTRZ 4) are also frequently caught. Fish stocked in southern Georgian Bay, the Bruce Archipelago and even northern Lake Michigan have also been recovered in this LTRZ.

The commercial fishery reported that the harvest and CPUE of lake trout began to increase in this LTRZ in the early 1990s. Harvest continued to increase through to 2005, peaking at just over 28,000 kg. Similarly, CPUE increased steadily, peaking at 17.5 kg/km in 2003. Since that time, CPUE has remained fairly constant, averaging 17.0 kg/km between 2004 and 2006. Despite the increase in relative abundance, the CPUE in this LTRZ is still moderate compared to other LTRZs.

The age distribution of lake trout sampled from this LTRZ has shown a distinct shift from the early 1990s to 2006. Prior to 1995, the age distribution was characterized by three to six year old fish. Fish older than six years of age were rare. Since that time, the number of ages in the age distribution has increased steadily. Between 2004 and 2006, the age distribution was dominated by five to eight year old fish, with fish as old as 19 being observed. Mortality estimates calculated using pooled data from 1990 to 1996 and 2004 to 2006 suggest that total annual mortality has dropped substantially in recent years (58.6% during the earlier period versus 29.4% more recently). The low mortality rate is consistent with the broad age distribution observed in recent years.

Although the age distribution of the lake trout sampled from this LTRZ has matured over the past several years, the mean age of fish continues to be below the mean age to maturity for lake trout in Lake Huron (between 6.0 and 6.6 years of age in 2004-2006).

Few unclipped (and presumably wild) lake trout have been observed in this LTRZ. Since 2002, only one unclipped lake trout has been documented (less than 1% of the fish sampled).

Sea lamprey marks declined from 15.0 marks per 100 fish (1990 to 1999) to only 3.7 marks per 100 fish (2000 to 2006) but has been trending upwards in the most recent years. The drop in lamprey wounding rates may be related to increased sea lamprey treatment in the St. Mary's River that started in 1998.

Current Status

No stocking of lake trout has taken place in this LTRZ; however immigration from U.S. waters is substantial. Adult mortality has, at times, been a significant impediment to establishment of a mature spawning stock in this LTRZ. Unlike historic conditions, it appears that sea lamprey abundance has dropped in recent years and as a result the deferred status of this LTRZ should be reconsidered. This LTRZ has not achieved the short term rehabilitation objective.

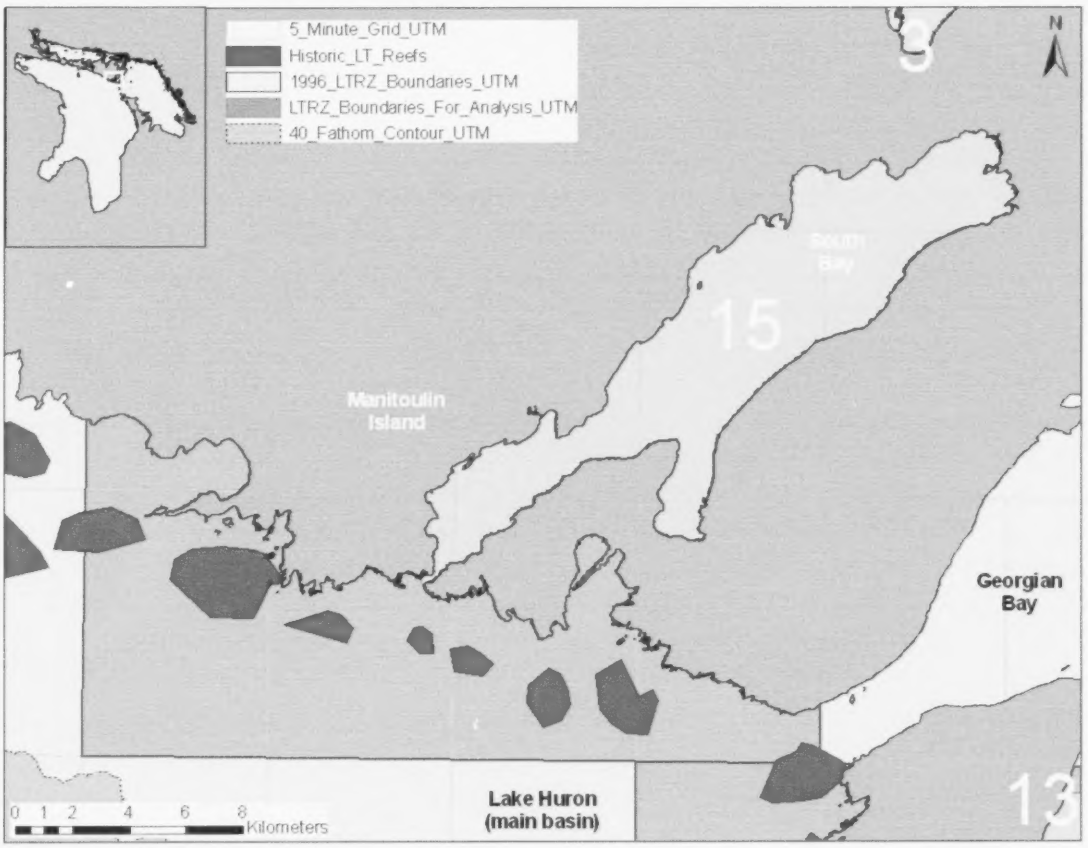
Recommendations

- Control sources of mortality and maintain total annual mortality below 40%
- Increase biological sampling from the commercial catch
- Reconsider the deferred status of this LTRZ
- Continue to monitor the lake trout population through the commercial fishery

Lake Trout Rehabilitation Zone 15

Lake Trout Rehabilitation Zone 15, South Bay, is a bay on Manitoulin Island open to the main basin of the lake (Figure 19). South Bay has two sub-basins, one deeper, larger basin to the north and a smaller, shallower basin to the south. Ample spawning habitat and deepwater habitat have been identified in the inner basin of South Bay and also in the near shore areas of Lake Huron close to the mouth of the bay.

Figure 19. The location of LTRZ 15, its boundaries according to the 1996 Lake Trout Rehabilitation Plan for Lake Huron (Canadian jurisdiction) (beige), the area assessed for this review (both beige and dark grey), lake trout spawning shoals, and the 40 fathom contour.



LTRZ 15 was identified in the 1996 Plan as an active zone with secondary protection class.

Commercial fishing is not permitted within South Bay. However, commercial style gill net gear has been used intermittently in a First Nation subsistence fishery. This fishery has traditionally targeted both lake trout and lake whitefish. Recreational fisheries also exist within South Bay, targeting lake trout, non-native salmonids and smallmouth bass.

High exploitation of lake trout in South Bay occurred during the early 1980s. As a consequence, the development of a significant spawning population and subsequent natural recruitment was

initially delayed. The introduction of commercial harvest controls in 1984 reduced the rate of exploitation, and allowed substantial population growth, which led to the production of the first natural year class of lake trout (since 1948) in 1990 (Anderson and Collins 1995). Recreational harvest may have also been an issue as a creel assessment conducted in 1990 estimated substantial harvest of lake trout (2 523 fish) (Anderson 1991). In contrast, a 2006 roving creel estimated that 79 lake trout were caught in South Bay (McAllister and Mohr 2006).

South Bay was stocked with splake from 1968 to 1975, followed by paired stocking of backcross and pure strain lake trout from 1977 to 1991. From 1977 to 1991, South Bay received a total of 463,762 stocked yearling trout, an annual stocking rate of 4 yearlings per ha. From 1992 to 2006, South Bay received a total of 365,947 yearling lake trout (primarily Lake Manitou strain), an average annual stocking rate of 2.8 yearlings per ha.

Since 2003, an average of approximately 8 600 lake trout with CWTs have been included in the stocking activities in this LTRZ. To date, none of these fish have been recovered. A small number of CWTs have been recovered in the commercial fishery just outside the bay. These fish were originally stocked in U.S. waters. Lake trout sampled in non-lethal spawning surveys in South Bay have been tagged with t-bar anchor tags, although none of these fish have been observed outside of the bay.

Lake trout captured in index gill netting studies in 1992 consisted primarily of stocked fish, only 3% of the fish were unclipped (OMNR unpublished data). By 1997, the proportion of wild lake trout captured in the index gill nets had risen to 27%. From 2001 to 2004 the catch of wild lake trout ranged from 84 to 89% (Yolanda Morbey, OMNR, Owen Sound, pers. comm.). The ratio of wild to hatchery fish continues to increase and the current average exceeds 50%, the benchmark for designating rehabilitated populations (Ebener 1998).

Between 2003 and 2004, the catch of wild lake trout was comprised of a variety of year classes from ages 3 to 13 with an average of 8.1 years of age. The spawning population is made up of several year classes and the mean age of female spawners is more than 1 year older than the age to maturity, exceeding the evaluation criteria defined in the Lake Huron lake trout rehabilitation plan (OMNR 1996).

Estimated total annual mortality is below 40% and sea lamprey marking rates are below the GLFC sea lamprey control targets for Lake Huron, averaging less than 2 marks per 100 fish.

Current Status

Rehabilitation of lake trout appears very encouraging in South Bay. Wild adults comprise a large proportion of the spawning population suggesting that the mid term rehabilitation objective has been achieved. While the adult population exhibits characteristics of a successfully rehabilitated population, recent low recruitment of wild fish, has raised the question of the future of lake trout rehabilitation in South Bay (Morbey et al. 2008). Continued assessment of this population is needed in order to ensure progress made to date is not compromised.

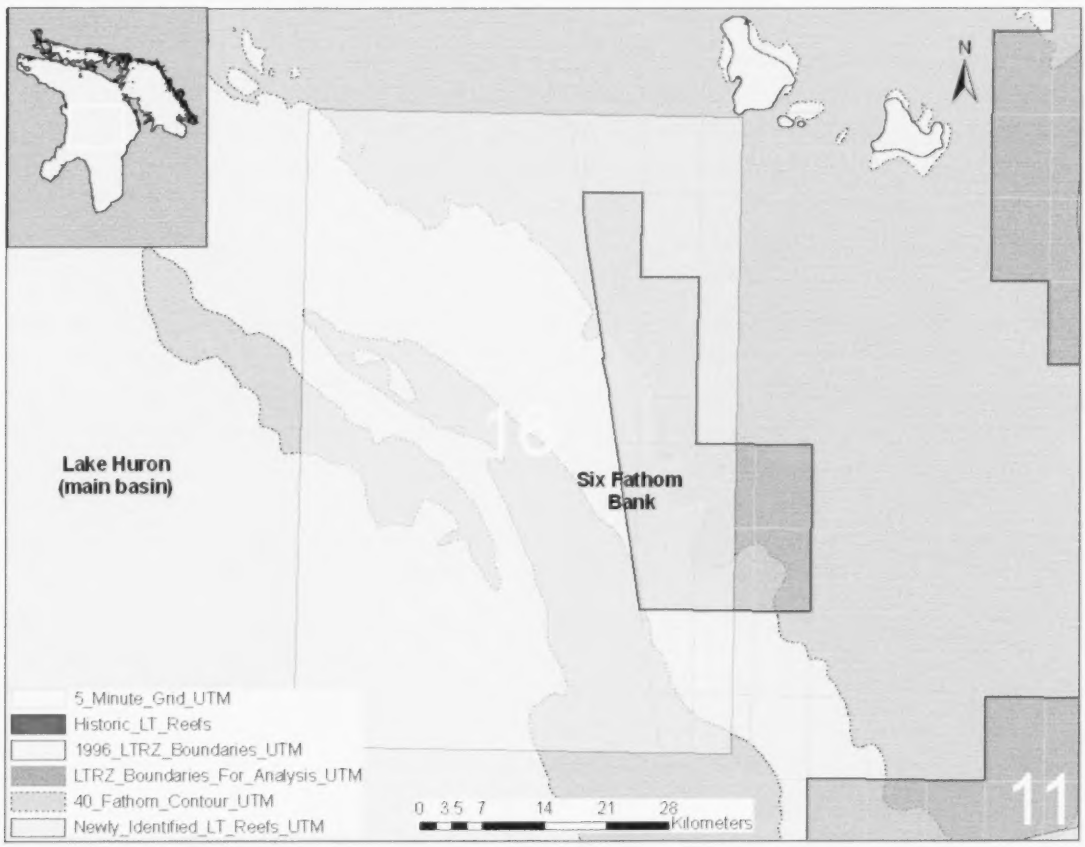
Recommendations

- Evaluate the need for continued stocking in this LTRZ
- Confine the boundaries of the LTRZ to both the inner and outer basins of South Bay
- Continue to monitor the spawning stock
- Determine why juvenile abundance is low in recent surveys
- Consider implementation of more restrictive angling regulations to protect burgeoning numbers of wild lake trout
- If possible, estimate population size through time in an effort confirm the presence of a stable, reproducing population

Lake Trout Rehabilitation Zone 16

Lake Trout Rehabilitation Zone 16, Six Fathom Bank, is located in the main basin of Lake Huron (Figure 20) approximately 55 km offshore. It straddles the international border between the State of Michigan and the Province of Ontario. Approximately one third of Six Fathom Bank is in Canadian waters. Spawning habitat has been identified on this reef along with significant amounts of deepwater in the immediate vicinity (Edsall et al. 1992).

Figure 20. The location of LTRZ 16, its boundaries according to the 1996 Lake Trout Rehabilitation Plan for Lake Huron (Canadian jurisdiction) (beige), the area assessed for this review (both beige and dark grey), lake trout spawning shoals, and the 40 fathom contour.



LTRZ 16 was identified in the 1996 Plan as an active zone with a primary protection classification. Since 1997, no commercial fishing activity has been allowed in Canadian waters of Six Fathom Bank shallower than 40 fathoms (73 m). There has been limited commercial fishing for deepwater chub in waters deeper than 40 fathoms to the east of the reef. The distance from shore limits recreational fishing activity.

No stocking has occurred in the Canadian waters of this LTRZ. Fish have been stocked in U.S. waters by the USFWS since 1985. Only pure strain lake trout have been stocked (McClain

2002). The average stocking density from 1985 to 1998 was 2.4 yearling equivalents per ha. No stocking has occurred on the reef since 1998.

All lake trout stocked on Six Fathom Bank were marked with CWTs. Lake trout stocked at Six Fathom Bank have been recovered from all regions of Lake Huron including Georgian Bay and the North Channel.

Relative abundance of lake trout on the reef appears to have remained quite high, even after the cessation of stocking. CPUE of lake trout in U.S. assessment programs has remained at a level considered to be adequate for natural reproduction, especially during fall gillnet surveys (Madenjian et al. 2004). Abundance estimates from spring and summer surveys are generally lower.

In addition to adult gillnet surveys, young-of-the-year trawling has been conducted to detect natural reproduction. The CPUE of age-0 lake trout peaked in 1994 but has declined ever since (Desorcie and Bowen 2003).

The incidence of unclipped lake trout in the gill net catches on Six Fathom Bank has been relatively rare. Madenjian (2004) reported a pooled value of 2.8% unclipped fish from 1992 to 2000. They further state that although wild age-0 fish have been observed on Six Fathom Bank, there appears to be no recruitment of those fish to the adult population. However, more recent data indicate that the proportion of wild adults is increasing, and is currently above the assumed background rate of 5% (Chuck Madenjian, USGS, Ann Arbor, pers. comm.).

From the mid 1990s to 2004, the average age of lake trout dropped from 7.7 years to 6.6 years of age.

Estimates of total mortality from 1992 to 2000 were 39.3%, although there were some differences amongst the different strains stocked on Six Fathom Bank (Madenjian et al. 2004). Lamprey wounding rates varied between strains and was higher than the GLFC target of 5.0 wounds per 100 lake trout for the various length classes and strains analyzed by Madenjian et al. (2004).

Current Status

Rehabilitation effort in the Ontario waters of Six Fathom Bank has been limited to restricting commercial activity. Stocking and assessment has been conducted by the USFWS and the USGS in Michigan waters of Six Fathom Bank. Although wild fish have been documented on Six Fathom Bank, and a substantial spawning stock of hatchery origin appears to exist, recruitment of wild fish to the adult population has been limited. It appears that LTRZ 16 has achieved the short term objective however, it is uncertain if the mid term rehabilitation objective has been reached.

Recommendations

- Support resumed stocking in Michigan waters of Six Fathom Bank until sustained natural reproduction is observed.
- Support continued assessment for the presence of an adult spawning stock in the zone
- Support continued monitoring for wild juvenile lake trout in the zone
- With U.S. partners, continue to designate the zone a refuge from fishing

STRATEGIC REVIEW OF THE 1996 LAKE TROUT REHABILTATION PLAN

The purpose of this section is to review the goal, objectives, strategies, and evaluation criteria outlined in the 1996 Plan for Lake Huron. Standardized assessment tactics are also discussed, along with the role that habitat and community interactions play in lake trout rehabilitation. Lastly, outstanding research questions are outlined.

GOAL

Rehabilitation of lake trout is supported by a number of strategic documents including the OMNRs Strategic Plan for Ontario Fisheries (SPOF II) (OMNR 1992), the Strategic Vision of the Great Lakes Fishery Commission for the First Decade of the New Millennium (GLFC 2001), and the international FCOs for Lake Huron (Desjardine et al. 1995). In addition, lake trout rehabilitation in the Great Lakes is also strongly supported by the scientific community (Selgeby et al. 1995).

The need for a stable, healthy aquatic ecosystem in Lake Huron has never been more urgent. An increase in the frequency of arrival and spread of new exotic invasive species has resulted in the constant disturbance of the lake's fish community (Leach et al. 1999). Re-establishing the native top predator in the open waters of Lake Huron is deemed the best approach to reduce the likelihood of non-indigenous species successfully establishing themselves and spreading across the lake (Leach et al. 1999).

Recommendations

With this in mind, the recommendation is to use the following goal for lake trout rehabilitation in Lake Huron:

> ***"To re-establish self-sustaining lake trout populations in Ontario waters of Lake Huron and thus contribute to a healthy aquatic ecosystem by facilitating stability as the dominant top predator while maintaining viable populations and sustainable harvests through natural reproduction"***

OBJECTIVES

As discussed in the review of rehabilitation efforts, lake trout rehabilitation is expected to follow a progression from a population that is entirely dependent on hatchery input, to one that has limited natural reproduction, to a population that is entirely self sustaining and is supported by natural reproduction alone. These three distinct phases can be categorized using short-term, mid-term and long-term objectives. The 1996 Plan provided short-, mid-, and long-term objectives that followed these three stages (OMNR 1996).

Although the objectives identified in the 1996 Plan followed the expected progression through lake trout rehabilitation, the objectives were tied to specific dates. The hard timelines used in the objectives of the 1996 Plan did not recognize that each LTRZ was not likely to follow the same

timeline. In hindsight, this was expected as the timeline for rehabilitation in any given LTRZ was influenced by the initiation of stocking pure strain lake trout, the presence and magnitude of exploitation, sea lamprey abundance and impacts from exotic species such as alewives.

In addition to the date specific nature of the objectives used in the 1996 Plan, the objectives were quite general in nature. For instance, the short term objective was focused on the development of spawning populations. However, it provided no quantitative definition of how a spawning population was to be measured. Also, the 1996 objectives were often not spatially specific and as a result, it was unclear what areas of the lake they applied too.

To clarify these uncertainties, the discussion below is intended to provide short-, mid-, and long-term objectives that take into account the commencement of pure strain lake trout stocking in each LTRZ, impediments to rehabilitation and are spatially specific. Finally, a more explicit definition of a spawning population is recommended, including characteristics that can be easily quantified and are consistent with the evaluation criteria which are discussed in detail later in this section. Pertinent to each objective, a spawning population is defined as:

- Average catch rates in excess of 17 spawning lake trout / 305m of large mesh gill net.
- Minimum catch rates of 12 adult lake trout / net night in trap nets.
- Minimum catch rates of 1.3 adult lake trout / hour in short set gill nets, either on or nearby to spawning habitat or at randomly selected sites within a LTRZ

Short-term Objective

The original short-term objective stated in the 1996 Plan was to "*develop spawning populations of lake trout by the year 2005*". Progress towards the first objective of rehabilitation is determined in large part by stocking history, stocking density, total annual mortality, and age to maturity. Together, these factors influence the establishment of a spawning population. The original objective failed to recognize how these factors differed between rehabilitation zones, and how the influence of these factors resulted in unique rehabilitation trajectories for each LTRZ. Additionally, characteristics of a spawning population that satisfied the first objective were not explicitly described.

The rehabilitation timeline, based on empirical data from Ontario waters of Lake Huron, suggests that measurable quantities of adult hatchery lake trout should be sufficiently abundant to produce measurable quantities of offspring 8-11 years following initial stocking of yearlings (Figure 2). This is consistent with the findings of Ebener (1998). This timeline assumes that exploitation and sea lamprey mortality are negligible and stocking densities are adequate. With this concept in mind, it is recommended that the original short-term objective be phrased in terms of 'years following initial stocking' rather than specific dates.

Recommendations

Given the rehabilitation timeline, a revision of the short-term objective presented in the 1996 Plan (OMNR 1996) is proposed as follows:

Short-term Objective:

Develop adult populations of lake trout capable of producing measurable numbers of wild offspring within 8 to 13 years of initial stocking of yearlings. Where

- *an "adult population" is defined as an aggregation of sexually mature lake trout, comprised of at least 3 different mature cohorts spawning in habitats with substrates suitable for egg deposition and rearing.*
- *the average age of mature lake trout is at least one year older than the age of first maturity (for each sex independently)*
- *a minimum of 5 stocking events, each of at least 2.5 yearlings per ha, have occurred in the LTRZ within an 11 year period*

Mid-term Objective

The original mid-term objective stated in the 1996 report was to "*generate natural reproduction of lake trout by the year 2010*". Like the original short-term objective, the year specific nature of the mid-term objective failed to recognize the different rehabilitation trajectories of individual LTRZs and the influence that this is likely to have on the production of wild lake trout. Additionally, key terms were not explicitly defined in the original mid-term objective.

Assuming that females begin to spawn at age seven, the rehabilitation timeline suggests that the first wild lake trout yearlings could be present as early as eight years after the initial stocking. These wild offspring would then be recruited to index gear as four year olds 11 years after initial stocking. Subsequently, we would expect to observe wild fish in the spawning population 14 years after initial stocking at seven years of age (Figure 2). Again, this timeline assumes that exploitation and sea lamprey mortality are negligible and original stocking densities were sufficient and that the attainment of the short term objective is sustained. With this concept in mind, it is recommended that the original mid-term objective be phrased in terms of 'years following initial stocking' rather than specific dates and that it reflect the expected presence of both wild juveniles followed by wild adult lake trout in each LTRZ.

Finally, more explicit definitions of wild juvenile and adult contributions to populations are provided, including characteristics that can be easily quantified.

Recommendations

A revised mid-term objective is proposed as follows:

Mid-term Objective:

Generate sustained and measurable natural reproduction of wild juvenile lake trout by the 11th year following initial yearling stocking and recruitment of these wild fish to the spawning population 14 to 19 years following initial stocking. Where:

- *natural reproduction is confirmed by the presence of a minimum of 3 wild juvenile cohorts*
- *wild adults from several year classes combine to make up more than 25% of the spawning population.*

Long-term Objective

The original long-term objective stated in the 1996 report was to "*Establish self-reproducing lake trout populations across much of their former range and supply, by the year 2020, an annual sustained yield of about 1.12 million kilograms (2.5 million pounds) of lake trout from the Canadian waters of Lake Huron.*" One problem with the original objective is that it is lake-wide in scope while the other objectives and subsequent rehabilitation efforts have operated on a zone by zone basis. As a consequence, there has been a disjunction between the mid-term objective, which applies to an individual LTRZ, and the original long-term objective, which applies to the lake as a whole. As an alternative, it is suggested that the long-term objective be revised to reflect the zone-specific nature of lake trout rehabilitation in Ontario waters of Lake Huron.

Like the original short- and mid-term objectives, the year specific nature of the long-term objective failed to recognize the different rehabilitation trajectories of individual LTRZs and the influence that this is likely to have on lake trout rehabilitation. Additionally, the key measure, yield, may not be an appropriate indicator of rehabilitation on a zone-by-zone basis. It may be more appropriate to examine parameters that reflect the stability of the rehabilitated population.

Recommendations

A revised long-term objective for individual zones is proposed as follows:

> *Long-term Objective:*
> ***Establish self-reproducing lake trout populations with a stable spawning stock, annual recruitment of wild fish, and total annual mortality rates less than 40%.***

The ultimate goal of rehabilitation remains the re-establishment of lake trout populations throughout Lake Huron. The revised long-term objective is consistent with this goal because successful rehabilitation in all of the individual LTRZs will facilitate the expansion of wild lake trout into all areas of Lake Huron formerly occupied by the species.

LAKEWIDE COORDINATON

While the existing rehabilitation plan (OMNR 1996) was developed for Canadian waters only, it is apparent that evaluation of rehabilitation progress cannot be completed without including basin-wide efforts. In particular, this applies to the main basin which is shared with the United States. In most cases, this may simply require integrating information from both U.S. and Ontario waters and gauging progress in terms of existing objectives. In other cases it may require consultation and integration of management and stocking strategies from all agencies in order to best address rehabilitation objectives.

Recommendation

> ***Lake trout rehabilitation in the main basin of Lake Huron should be integrated as a lake-wide strategy in partnership with other management agencies.***

REHABILITATION STRATEGIES

Rehabilitation strategies can be divided into four general categories: the identification of discrete areas for rehabilitation, stocking methods, exploitation control and control of sea lamprey mortality. Sixteen discrete LTRZs were identified in the 1996 Plan, areas where the probability of successful rehabilitation was expected to be high. The identification of these areas continues to facilitate focused management and assessment actions. Stocking strategies include various options available such as stocking densities, strain selection and life stage stocked. Exploitation control includes management actions that can be implemented to minimize mortality from commercial and recreational fisheries. Additionally, lamprey mortality can be a significant source of overall lake trout mortality in some parts of Lake Huron, but control of lamprey is beyond the mandate of the UGMLU. However, the UGLMU advocates for the continued control of sea lamprey through the GLFC and its affiliate agencies and provides feedback to the GLFC control agents as to effectiveness of control within each of Ontario's LTRZs. Given that sea lamprey control is beyond the mandate of the UGLMU, specific recommendations regarding this program will not be made other than to advocate for continued OMNR assessment of sea lamprey marking rates and attainment of sea lamprey control targets by the GLFC and associated control agencies. Finally, those areas with remnant lake trout stocks deserve special consideration when selecting appropriate rehabilitation strategies to ensure that remnant stocks are conserved.

While strategies for rehabilitation can be described in a global context, each LTRZ is unique and therefore can have unique needs. Treating them individually by developing LTRZ specific rehabilitation plans ensures focused rehabilitation efforts with defined strategies, avenues for adaptation, and means of measuring success in each LTRZ.

Recommendations

In addition to general lake trout rehabilitation strategies, it is recommended that the following components be developed for each LTRZ:

- ***an explicit stocking plan,***
- ***an explicit management approach designed to control exploitation,***
- ***a complete assessment plan including evaluation criteria which will be used to evaluate progress, and***
- ***time lines for the evaluation of progress towards each rehabilitation objective.***

Rehabilitation Zones

Zone Definition

The identification of LTRZs, one of the four main strategies, focuses rehabilitation efforts in discrete areas where a high probability of successful rehabilitation is expected. In the 1996 Plan, 16 LTRZs were identified which covered most of the areas in the lake with historical lake trout spawning habitat (Smith 1968). However, not all of the zones were clearly defined spatially and

the extent of these areas did not conform to any standard reporting protocol used by the UGLMU. Additionally, no deepwater spawning reefs were included in the original plan.

Over the past several years, additional information regarding habitat preferences, rehabilitation successes (Reid et al. 2001), and movement of stocked lake trout has been gathered which suggests that the spatial criteria for LTRZs should be re-visited (Ebener 1998). For example, habitat could be used to define the boundaries of the LTRZs more precisely. This approach was recommended in the Lake Huron Rehabilitation Guide (Ebener 1998) where it was suggested that lake trout rehabilitation efforts be focused in waters less than 40 fathoms (73 m) in depth. In addition to consideration of habitat preferences, movement, and rehabilitation successes, LTRZ borders need to conform to the spatial aspects of existing data reporting systems (i.e. 5 minute grid system).

One habitat type that was missed when the original LTRZs were developed was deepwater spawning reefs. Historically, these areas provided critical habitat for deepwater forms of lake trout in Lake Huron (Eshenroder et al. 1995*a*). Hansen et al. (1995) suggested that the successful recovery of lake trout in Lake Superior was at least partially due to the presence of offshore, deepwater lake trout strains. Preliminary underwater video reconnaissance in north-central Lake Huron suggests that reefs in this zone may provide appropriate spawning and larval habitat for lake trout. These areas could form new LTRZs where establishing populations of deepwater lake trout strains would be a priority.

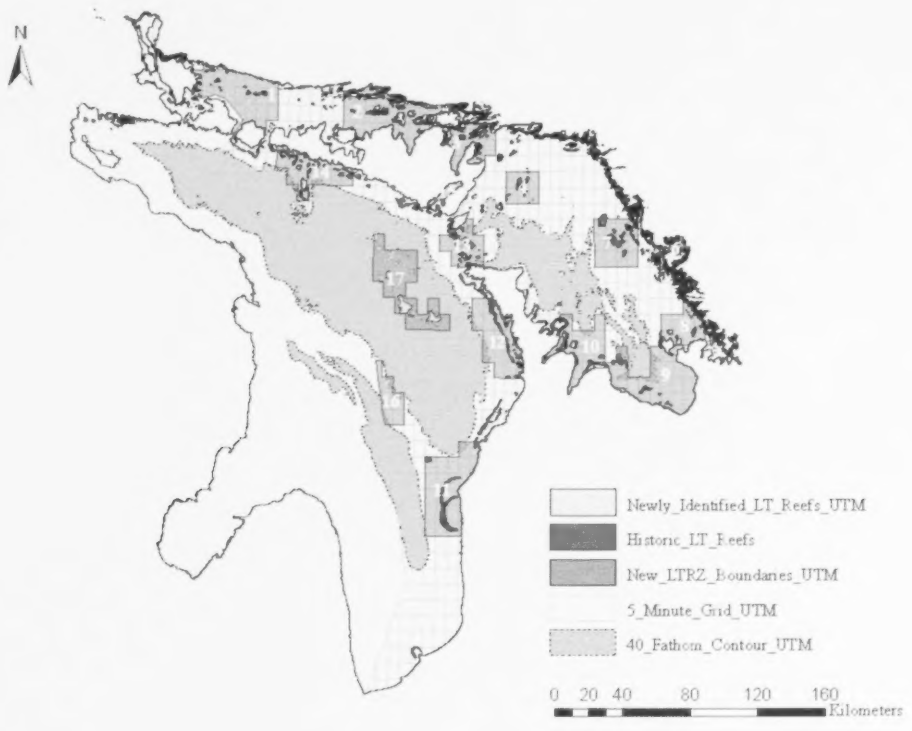
Lastly, the large size and complicated nature of some LTRZs has proven to be prohibitive to assessing progress. This is particularly true when natural features fragment zones into discreet sub-areas. For example, the original LTRZ 10 extended from Cabot Head at the northern tip of the Bruce Peninsula, to Cape Rich in southwestern Georgian Bay. When habitat using the 40 fathom contour line is considered, as defined by Ebener (1998), this zone can be divided at Cape Croker (Figure 21). Documented natural reproduction in Owen Sound Bay and lack of movement between the northern or southern halves of the zone (defined by the 40 fathom contour line) suggest that LTRZ 10 may be more appropriately defined as the area from Cape Croker south to Cape Rich. The area north of Cape Croker would not be part of a LTRZ as a result.

Recommendations

The following changes to LTRZs are suggested:

- ***Revised spatial descriptions of the original LTRZs are given in Figure 21. These zones have been delineated based upon suggested habitat requirements (<40 fathom depth), historical spawning habitat (Smith 1968), and the 5 minute grid reporting system currently employed by the UGLMU.***
- ***A new LTRZ (LTRZ 17) be created as a potential offshore rehabilitation site for deepwater lake trout strains (Figure 21).***
- ***The boundaries of LTRZ 10 will be redefined to only include the existing area south of Cape Croker to Cape Rich. Any stocking occurring north of Cape Croker will be re-allocated to sites within this new area.***

Figure 21. Recommended Lake Trout Rehabilitation Zones for Lake Huron.



Zone Classification

LTRZs were originally classified by both "Rehabilitation Status" and "Protection Class" (OMNR 1996).

Rehabilitation Status reflected recognition of whether or not rehabilitation was likely attainable under proposed timelines. Rehabilitation status for each LTRZ was classified as either active or deferred. Active rehabilitation zones were those LTRZs where no major impediments to rehabilitation were thought to exist. Deferred rehabilitation zones were those LTRZs where one or more major impediments had been identified and as such, stocking was not conducted. Impediments included excessive mortality due to lamprey abundance or large-scale gill-net fisheries. For the most part, impediments to lake trout rehabilitation remain in some LTRZs making the rehabilitation status designation a meaningful approach. However, it has become apparent that the deferred designation referred to stocking specifically and not necessarily fisheries assessment. In LTRZs designated as deferred, standard, year-to-year assessment projects such as commercial catch sampling were still conducted in an effort to monitor other portions of the fish community other than lake trout. Lake trout data were still collected in these types of assessment programs and have been useful in evaluating the status of lake trout in deferred zones. For zones where stocking will not be conducted due to the continued presence of major impediments, the deferred designation might be more appropriately termed 'in-active' as lake trout will not be stocked or actively targeted in assessment projects. However, for in-active LTRZs any impediments to rehabilitation will continue to be monitored.

Protection class defined the degree of protection through regulation and included three distinct classifications. LTRZs having a primary protection classification were to be regulated as sanctuaries. No fishing, either recreational or commercial, is allowed in sanctuaries. Lake trout in LTRZs with a secondary protection classification could be protected from excessive exploitation through implementation of more restrictive license conditions and recreational fishing regulations. Lake trout in LTRZs with a tertiary protection class were protected by existing commercial and recreational fishing regulations. Based on experiences since the 1996 Plan was published, it became evident that protection class did not reflect rehabilitation priorities which were (in most cases) dictated by expectations for success. A more meaningful alternative would be to explicitly rank each LTRZ using a scoring system based on attributes that are expected to promote or impede rehabilitation. This ranked list would then identify priority LTRZs for stocking, assessment activities and implementation of protective regulations.

The list of attributes used in this scoring process, as presented in Appendix 2, have been deemed to be those most important to rehabilitation, as discussed by Argyle et al (1991), OMNR (1996), and Ebener (1998). Of the list of attributes used to score LTRZs, existence of a remnant stock, possibility for exploitation control, low lamprey wounding rates and the presence of unmarked fish were deemed the most important attributes for rehabilitation efforts and were weighted with a maximum score of two, out of possible range of scores from zero to two. The higher maximum scores for these attributes reflects their heightened importance to successful rehabilitation. The other attributes used to score LTRZs, proximity to a remnant stock, and the consistency with which the stocking target has been met, were weighted with a lower maximum value of one due their perceived reduced influence on rehabilitation. The status of rehabilitation in each LTRZ, as

presented in the previous section, formed the basis of the information used to score each LTRZ. If any of the attributes used to score the LTRZs were not present or attained in any LTRZs, a score of 0 was assigned; in the case of attributes with a maximum score of two, a score of one was assigned if the attribute was partially met or attained.

With this approach, the highest scoring LTRZs would receive the highest priority in the rehabilitation process. The scores that each LTRZ receive and their place in a ranked list based on the score (Table 2) would reflect the expectation for rehabilitation success, emphasize the protection of remnant stocks, consider the ability to manage exploitation, and incorporate other management priorities.

Recommendations

It is recommended that:

- ***The Protection Class designation be replaced by a priority ranking of all LTRZs based on a scoring system as presented in Table 2 and Appendix 2.***
- ***The "Status" classification approach, which describes whether rehabilitation efforts are currently taking place or not, should be maintained. However, the designation of Deferred should be replaced by an in-active designation to more accurately reflect both the absence of stocking and the collection of lake trout data in non-targeted sampling programs. This designation should be identified in the rehabilitation plans for each LTRZ.***

Table 2. Description of Lake Trout Rehabilitation Zones for Lake Huron, objective achieved for each zone (as of 2006 according to the 1996 Plan), the proposed priority ranking and proposed rehabilitation status.

LTRZ Number	Name	Basin	Priority (Rank)	Current Rehabilitation Status	Proposed Rehabilitation Status	Objective Achieved
6	Parry Sound	Georgian Bay	1	Active	Active	Long Term
5	Iroquois Bay	North Channel	2	Active	Active	None
15	South Bay	Main Basin	3	Active	Active	Mid Term
7	Limestone Islands	Georgian Bay	4	Active	Active	None
3	Fraser Bay	North Channel	5	Active	Active	None
4	Grand Bank/Dawson Rock	Georgian Bay	6	Active	Active	None
16	Six Fathom Bank	Main Basin	7	Active	Active	Short Term
10	Owen Sound/Colpoys Bay	Georgian Bay	8	Active	Active	None
12	Western Bruce Penninsula	Main Basin	9	Deferred	In-active	None
9	Nottawasaga Bay	Georgian Bay	10	Active	Active	None
8	Watcher Islands	Georgian Bay	11	Active	Active	None
14	SW Manitoulin Island	Main Basin	12	Deferred	In-active	None
13	Bruce Archipelago	Georgian Bay	13	Active	Active	None
17	North Lake Huron Humps	Main Basin	15	Deferred	In-active	NA (new zone)
11	Point Clark	Main Basin	16	Active	Active	Uncertain
1	Western North Channel	North Channel	17	Deferred		None
2	Darch Islands	North Channel	18	Active	Active	None

Stocking

Stocking continues to be one of the most important management tools for the rehabilitation of lake trout in Lake Huron. Stocking density, strain selection, stocking locations/methods, and size and age of the stocked fish are key factors to consider. Additionally, marking of stocked fish provides crucial information that cannot be easily obtained by other methods. The 1996 Plan made a number of recommendations with respect to stocking activities including minimum densities, strains and life stages, and frequency. However, the original report provided little guidance about marking, either by fin clipping or application of CWTs. Additionally, since the 1996 Plan was written, pulse stocking and other new stocking practices have been implemented on Lake Huron to maximize survival of stocked fish (McClain et al. 1995).

Stocking Density

Appropriate stocking densities are the first step towards the development of a sufficiently large spawning stock. The density at which fish are stocked needs to consider total annual mortality and age to maturity in the LTRZ. All things being equal, a zone with higher mortality will require higher stocking densities to achieve an adult spawning population of a certain size than a zone with a lower mortality rate. Similarly, age to maturity can also influence the number of

stocked yearlings required to achieve a pre-defined spawning biomass. Zones where fish mature at a later age will require higher stocking densities as fish are exposed to sources of mortality for a longer period before they contribute to the spawning population. For instance, Madenjian et al. (1998) discussed how a delay in maturity of only two years can result in a 50% reduction in the size of the spawning population.

For the Canadian waters of Lake Huron, the recommended stocking density has been 2.5 yearling equivalents per ha of habitat (OMNR 1996). This stocking rate produced high densities of lake trout in Lake Superior (Lake Superior Lake Trout Technical Committee 1986; Hansen et al. 1995).

In reviewing the stocking densities in the LTRZs identified in the 1996 Plan, 8 of the 11 zones undergoing rehabilitative stocking since 2000 met or exceeded the 2.5 yearlings per ha stocking target. In several zones where fish have been stocked at or above 2.5 yearlings per ha, sufficiently large spawning stocks have failed to develop despite high survival of stocked fish. However, Reid et al. (2001) suggested that one reason for the successful rehabilitation observed in Parry Sound was the high stocking rates which averaged 4.5 yearlings per ha over a 17 year period, substantially higher than the current benchmark. Currently Parry Sound is the only successfully rehabilitated lake trout population in Lake Huron. As such, higher stocking densities should be considered in other LTRZs. In addition to a recognized need for higher stocking densities, Ebener (1998) highlighted the propensity of lean lake trout strains to use water shallower than 40 fathoms. As a result, calculation of total stocking numbers for each zone should consider a density of 4.5 yearlings per ha, with surface area (hectares) representing the area within the new LTRZ boundaries that is also shallower than 40 fathoms.

Although stocking plays a key role in achieving rehabilitation, stocking also needs to be considered when natural reproduction is observed. Ebener (1998) suggested that stocking rates should be reduced when wild lake trout comprise 25% of the mature portions of a population and that stocking be terminated when 50% of mature fish are wild. This recognizes that stocked fish are likely to have a negative influence on wild fish (as described by Evans and Willox (1991)) and that when natural reproduction is observed the presence of stocked fish should be minimized through reduced stocking.

Recommendations

The current recommendation of 2.5 yearling equivalents per ha should be considered a minimum stocking rate for lake trout rehabilitation. While some evidence of natural reproduction exists in a few of the LTRZs receiving this level of stocking of pure strain lake trout, creation of an adult spawning stock to facilitate sustained natural reproduction may require higher stocking rates in the range of 4.5 to 6 yearlings per ha. We recommend:

- ***a stocking rate of 4.5 yearlings per ha be used***
- ***total stocking numbers using this target density should be calculated based on the surface area within the new LTRZ boundaries that is shallower than 40 fathoms***

- ***when natural reproduction is documented, lower stocking densities or termination of stocking should be considered (see more specific details under the natural reproduction criteria for Progress Evaluation)***

Stocking Strains

The use of several strains of lake trout is recommended in both the 1996 Plan (OMNR 1996) and the Lake Huron Rehabilitation Guide (Ebener 1998). Several different strains of lake trout have been stocked in the Canadian waters of Lake Huron. These include:

- Parry Sound (Georgian Bay remnant stock)
- Iroquois Bay (Georgian Bay remnant stock)
- Lake Manitou (inland lake strain from Manitoulin Island, Lake Huron)
- Michipicoten Island (Lake Superior strain)
- Slate Island (Lake Superior strain)
- Seneca Lake (inland lake strain from New York State)

Evidence of measurable levels of natural reproduction has been observed in at least three LTRZs in Lake Huron. In Parry Sound, genetic analysis indicated that use of the remnant strain led to the production of wild juveniles (Stott 2004). The rehabilitation of the Parry Sound population using stocked juveniles from the remnant strain has lead to the stocking of this strain in other LTRZs. Though it was not a specific target in the 1996 Plan, the establishment of the Parry Sound and Iroquois Bay strains in OMNRs fish culture system was identified as an important action after the 1996 Plan was implemented. This was done to allow the more widespread use of native strains in the UGLMU's lake trout rehabilitation program for Lake Huron. Most recently, international collaboration is resulting in the establishment of a Parry Sound brood stock in the USFWS hatchery system. Yearlings produced from this brood stock will be stocked in Michigan waters of Lake Huron starting in approximately 2012. The Parry Sound experience has also lead to the use of Iroquois Bay and Lake Manitou strains (both Lake Huron basin strains) in other LTRZs. Use of the Lake Manitou strain has proven successful in both South Bay and Owen Sound Bay where the production of wild fish has been confirmed to be a result of stocking Lake Manitou fish (Stott 2004). It is too early to evaluate whether the use of the Iroquois Bay strain has lead to natural reproduction in locations where it has been stocked.

In order to determine if the available lake trout strains perform differentially, a number of paired-plant experiments have been initiated. These include a paired plant of Michipicoten and Slate Island strains which ran from 1994 through 1998 in LTRZ 9, an ongoing paired plant of Parry Sound and Seneca strains in LTRZ 2 which started in 1999 and an ongoing paired plant of Iroquois Bay and Parry Sound strains in LTRZ 9 which started in 2001. Analysis of results from these experiments is currently being conducted; however preliminary findings suggest that Michipicoten and Seneca strain lake trout have higher returns to fisheries (UGLMU unpublished data). Additionally, the Seneca strain has an older mean age than the Parry Sound strain; however these mean ages are below five years of age. As both of the current paired plant experiments have been conducted for at least eight years (the length of one generation for lake trout), it is likely that the stocking portions of the experiments can be terminated and pending analysis of the results, a decision made as to what strain continues to be stocked (if required).

In addition to the importance of native strains, the contributions of deepwater forms of lake trout to rehabilitation have been highlighted, particularly on Lake Superior (Hansen et al. 1995). Eshenroder et al. (1995*b*) also speculated that deepwater forms may be critical to restoring lake trout given their propensity to spawn in remote locations. Furthermore, Eshenroder et al. (1995*b*) noted that deepwater forms would contribute to overall genetic diversity of lake trout. Recent examination of the deepwater reefs in the main basin of Lake Huron (UGLMU unpublished data) suggests that these habitats are suitable for lake trout reproduction and are potential candidate locations for stocking.

Currently only one deepwater strain of lake trout is stocked in the Great Lakes, the Klondike strain (from Klondike reef on Lake Superior). This strain has been stocked into Lake Erie since 2004. Initial attempts to stock this strain in Lake Huron have met with resistance due to the perception that these fish would grow slowly and compete with or prey upon juveniles of the lean strains. In addition, it was thought this strain would have a high lipid level and as a result, be unappealing for human consumption. Lastly, concerns regarding contaminant levels due to slow growth and high lipid levels have been expressed by some stakeholders, however Miller et al (1992) suggest that lipid content and contaminant burdens are not closely correlated and that lean strains can accumulate higher levels of contaminants if the fish present in contaminated, nearshore habitats. Early assessment of this strain on Lake Erie has been encouraging with higher returns to assessment gear than other strains. Although their growth rates have been slower than other strains on Lake Erie, they are still relatively large fish averaging 22 inches long at four years of age versus the normal 24 inches long at the same age for other strains in Lake Erie. There is also no evidence that their lipid levels make them undesirable for human consumption. It is hoped that they will mature at smaller sizes and therefore reproduce before sea lamprey mortality becomes a significant impediment. More time is required to assess their propensity to accumulate contaminants in Lake Erie. This strain appears to be a suitable candidate for stocking offshore reefs in Lake Huron as well (Jim Markham, NYDEC, pers. comm.).

Recommendations

The following strain recommendations should be considered:

- ***Continue to give priority to lake trout strains native to the Lake Huron basin (Parry Sound, Iroquois Bay and Lake Manitou).***
- ***Preference should also be given to those strains that are most closely genetically related to Lake Huron strains, likely the two Lake Superior strains.***
- ***Seneca strain lake trout should only be stocked in LTRZs where sea lamprey abundance is an impediment to rehabilitation***
- ***Terminate the stocking portion of the current paired plant experiments; finalize and incorporate results into future stocking plans***
- ***A deepwater lake trout strain should be stocked and assessed in the offshore areas identified in the main basin of Lake Huron.***

Size and Age at Stocking

As discussed by Elrod et al. (1988) and Madenjian et al. (2004) larger, older fish at the time of stocking have increased survival compared to smaller fish. Additionally, larger fish are also easier to mark by either fin clips or CWTs, an important consideration when differentiating wild fish from hatchery fish. As a result of these considerations, Lake Huron stocking is currently conducted in the spring using yearling fish rather than younger, smaller life stages.

Recommendations

- ***It is recommended that yearling lake trout continue to be stocked in Ontario waters of Lake Huron.***

Marking

The ability to identify hatchery fish is critical for evaluating lake trout rehabilitation. Important benefits of marked fish are that they allow hatchery fish to be easily identified, assigned a known age, assessed for fish movement, allows for estimation of population size, and facilitate comparisons of different strains. Without marking all stocked fish it is extremely difficult if not impossible to measure the progress towards rehabilitation objectives, particularly in later stages of rehabilitation where progress is measured by the presence of unmarked, wild fish.

Currently, all lake trout stocked in Lake Huron are marked with fin clips. An adipose fin clip is used to identify lake trout that have been marked with a CWT. All other lake trout are marked with one of six unique fin clip combinations that are applied to the pectoral and pelvic fins. A six year rotation of these fin clips is used. This rotation allows the separation of individual cohorts in all but the oldest fish.

Coded wire tags are also being used throughout Lake Huron. Data from CWT returns are particularly valuable when assessing movement of stocked fish, evaluating different lake trout strains, and assigning ages. Currently, OMNR applies coded wire tags to approximately 20% of lake trout at each stocking site. The combination of fish with paired fin clips and fish with CWTs maximizes the information that can be obtained in subsequent assessments. Data from fin clipped fish can provide age and growth information without lethal sampling, while the presence of fish with CWTs provides more detailed information that cannot be easily obtained by other means.

Recommendations

- ***It is recommended that all stocked lake trout continue to be fin clipped using the 6 year clip rotation.***
- ***A minimum of 20% of all fish stocked in each LTRZ should be coded wire tagged in order to evaluate movement, validate ages and compare different strains.***

Other Stocking Strategies

Annual stocking procedures mimic constant recruitment which is generally uncharacteristic for many fish species. Wild lake trout routinely experience variable year class strength due to factors such as environmental conditions and community effects. In some species, the production of unusually large year classes has been shown to adversely affect subsequent population size, survival, growth, and reproduction for many years (Hile and Buettner 1959). Dunlop and Brady (1998) reported positive effects on stock abundance and wild recruitment in lake trout and brook trout populations after stocking was discontinued in Ontario lakes. Reid et al. (2001) also suggested that recruitment of wild lake trout in Parry Sound was highest during a period of non-stocking.

Since the late 1990s, LTRZs 7 and 8 have been pulse stocked, a stocking approach which entails a repeating cycle of three years of intense stocking followed by a three year stocking hiatus. The purpose of this intense, but irregular stocking is to more closely emulate natural recruitment patterns of wild lake trout and avoid intra-specific competition and cannibalism. It is expected that repeating three full cycles of three years of intense stocking followed by a three year stocking hiatus will allow effective evaluation of this approach.

Predation on fingerling and yearling lake trout at the time of stocking can contribute to significant mortality (Jones et al. 1995). Stocking in areas not frequented by predators or at times when predators are not actively feeding (i.e. at night), may increase the probability of successful recruitment from the stocking event.

Additionally, stocking yearling lake trout directly on spawning reefs (rather than in the vicinity of the spawning reefs) has been shown to substantially increase not only the survival of stocked fish (Johnson et al. 2004*a*), but the return rates to that spawning location as adults (Bronte et al. 2007). In many LTRZs, stocking fish directly on spawning reefs will require stocking all fish by boat.

Recommendations

Other stocking strategies should be investigated and evaluated.
These include:

- ***Existing pulse stocking strategies should be continued for three full cycles, evaluated, and expanded to other priority rehabilitation zones if they prove successful.***
- ***Stocking directly on spawning habitat, by boat if required, is the preferred method, particularly in the case of offshore LTRZs.***
- ***Night stocking should be thoroughly evaluated as a tool to reduce daytime predation by both avian and aquatic predators.***

Exploitation Control Measures

Lake trout have a number of life history attributes that require special consideration for exploitation management. First, they grow slowly and mature at older ages (5-8 years) relative to other salmonid species (Scott and Crossman 1973; Olver et al. 1991). In addition, they have

relatively low reproductive potential and long life expectancies (Evans and Olver 1995), attributes which make lake trout vulnerable to over exploitation.

Commercial and recreational fisheries are often selective, targeting the early maturing segment of a population. In combination, these two sources of mortality can have major impacts on rehabilitation efforts (Christie 1973; Baldwin et al. 1979; Hansen 1999; Evans and Olver 1995).

The lake trout data reviewed in this report reveal that in many instances, even the short-term rehabilitation benchmarks have not been achieved. The ongoing presence of commercial and recreational fisheries in LTRZs appears to be playing a substantial role in these failures. Strictly controlled exploitation was identified as a key factor in the successful rehabilitation of lake trout in Parry Sound (Reid et al. 2001).

Sport Fishery Management

A variety of techniques exist to manage recreational fisheries. While some can be applied to any species, others are likely best suited to long lived, coldwater species such as lake trout. The primary strategies used to limit harmful effects of recreational fishing on lake trout populations are described below.

Season closures are often used to protect fish from harvest during their spawning period (Noble and Jones 1993). In the case of lake trout, this normally means a closure during the fall. For example, the current fall closure on Lake Huron is from September 30th to December 1st. Evans et al. (1991) highlighted the need to consider winter closures for lake trout due to increased vulnerability to angling during the winter months, at least in areas where ice cover prevails during winter allowing for ice fishing access.

Sanctuaries have been used to protect sensitive areas, usually spawning areas or areas containing remnant stocks (i.e. the Grand Bank/Dawson Rock area and Iroquois Bay). The Dawson Rock area in northern Georgian Bay has been identified as an offshore area of high quality lake trout spawning habitat and is the only large scale, year round, lake trout specific sanctuary established in Ontario waters of Lake Huron. However, sanctuaries are not limited to spawning habitat. Large areas without exploitation often allow population biomass to increase such as in the Northern Refuge of Lake Michigan (Madenjian and DeSorcie 1999) and in many parts of Lake Superior (Schram et al. 1995). In Parry Sound a lake trout refuge has been used to protect the remnant stock in a vulnerable location and allow expansion into other areas. This area is closed to lake trout fishing year round but fishing for other species is allowed.

Catch and possession limits are perhaps the most widely used management tool to limit recreational fishery harvest. While bag limits serve to regulate the number of fish that can be harvested by an individual fisherman, they are rarely effective in controlling total harvest as many creel surveys show that the average angler does not normally catch the allowed limit (Olver 1969). Catch limits can be used in association with other restrictions to protect specific segments of the population from harvest.

Size limits can be used to minimize exploitation of a specific segment of the population. Minimum length limits (harvest allowed above a specified value) are normally used to allow more fish to reach sexual maturity, by protecting juveniles until they recruit into the adult segment of the population (Noble and Jones 1993). However, intense fisheries can produce excessive harvest of mature fish thereby reducing spawning stock biomass. Maximum length limits (harvest allowed up to a specified size) are used to explicitly protect large, sexually mature fish. This control strategy was used in Parry Sound to protect brood stock from harvest in order to allow continuing and increased recruitment of wild juveniles (Reid at al 2001). A maximum length limit is also a useful strategy in locations where mature fish are already present by providing protection to the reproductive portion of the population.

Selective harvest of stocked lake trout is a strategy that is particularly useful where hatchery fish are externally marked with fin clips and are mixed with wild fish. Fin clipping of hatchery fish allows the selective harvest of stocked fish and the release of wild fish. This maintains harvest opportunities but provides protection for wild fish. This strategy was implemented in Iroquois Bay (LTRZ 5) in an effort to provide protection for wild fish and promote their recruitment to the spawning population.

Catch and release regulations are sometimes used to reduce fishing mortality while still allowing fishing opportunities. While hooking mortality does occur, studies have shown that, when properly handled, high percentages of lake trout can survive catch and release angling (Barnhart and Engstrom-Heg 1984; Loftus et al. 1988; Quinn and Hicks 1988; Dextrase and Ball 1991). This management tool allows managers to sustain socio-economic benefits that accrue from recreational fishing activities while limiting exploitation and fishing mortality.

Recommendations

Recreational fishing regulations need to be implemented that consider the current stage of rehabilitation where the regulation will apply. Recreational regulations should also consider existing commercial, aboriginal, and subsistence fisheries regulation. The following options are recommended:

- ***That existing sanctuaries be maintained***
- ***New sanctuaries be considered in high priority areas.***
- ***Maintain current closed season in all LTRZs.***
- ***Where winter exploitation is considered to be excessive, closed winter seasons (Sept 30th to May 1st) should be considered.***
- ***Reduced bag limits to one or no lake trout in possession should be considered in rehabilitation zones with limited spawning stock biomass.***
- ***Where natural reproduction of lake trout is evident and the long term rehabilitation objective has not yet been achieved, we recommend the implementation of a "no wild fish harvest" regulation.***
- ***The use of size limits should be considered in active LTRZs, the specific restriction will depend on the current status of the LTRZ.***
- ***Educate anglers in proper lake trout catch and release techniques.***

Commercial Fishery Management

Commercial fisheries on Lake Huron are essentially managed using two tools, 1) quotas or total allowable harvests, and 2) conditions of fishing. Quotas are limits on the total harvest in a defined spatial region (i.e. - quota management area (OMNR 1982)) and are implemented on Lake Huron through individual commercial fishing licences. Conditions placed on commercial fishing licences and agreements limit the types of fishing effort that can be used, the types or configuration of gear deployed, spatial restrictions, and seasonal restrictions to fishing, among other things. The following text briefly describes the major strategies and tools for management of the commercial fisheries on Lake Huron with respect to lake trout.

Lake trout are currently a quota managed species in Lake Huron. These quotas are adjusted annually based upon stock status evaluations. Originally, lake trout quotas in most areas of the lake were small, based upon the historic incidental catch of lake trout while targeting other species, mainly lake whitefish. As lake trout populations increased in Lake Huron (concurrent with intensified stocking), historic quotas were re-evaluated and adjusted accordingly. These adjustments were made by balancing the increasing catch of lake trout with rehabilitation objectives. While quotas may control the total harvest of lake trout, they do little to protect specific segments of the lake trout population (i.e. juveniles and/or spawners) nor do they assure that the those lake trout that are released survive. Population effects of lake trout discards should be assessed by contrasting the number of fish released (which currently may not be regularly reported) with the number of fish that actually survive handling (Johnson et al. 2004b).

Two types of commercial gear are used in Lake Huron, gill nets and trap nets. Unlike gill nets, trap nets allow for the live release of incidentally caught fish and hence are beneficial in reducing lake trout harvest and mortality (Johnson et al. 2004*b*). Gill nets, and to a lesser extent trap nets, are often selective in the size and species of fish caught. Both minimum and maximum gill net mesh size restrictions are used in Lake Huron to control which species are targeted and also the size of fish likely to be caught in the gear. The current commercial minimum size for harvesting lake trout is 44 cm TL (17 inches), all fish smaller than this must be released alive if possible. Mesh size can also be used to protect larger fish which comprise the majority of the spawning stock.

Gear deployment can also be used as a management tool in commercial fisheries. Gill nets are most often fished on the lake bottom. However, by floating nets slightly above the lake bottom, lake trout can often be avoided while more pelagic species such as lake whitefish can still be effectively caught. In addition, depth restrictions can limit by-catch of lake trout.
As with recreational fisheries, season closures can be used to protect spawning lake trout, particularly as rehabilitation progresses and spawning populations become more abundant.

Sanctuaries or restricted fishing areas can also be used to protect certain populations and eliminate effort in sensitive areas. Currently two sanctuaries exist in Lake Huron, the Northern Refuge in U.S. waters of the main basin, and Grand Bank in Georgian Bay. It has been suggested that sanctuaries promote rehabilitation by eliminating fishing mortality and allowing mature spawning stocks to develop within their boundaries (Madenjian and DeSorcie 1999).

Recommendations

Commercial regulations need to be implemented that encourage and support lake trout rehabilitation. These regulations should compliment not only the stocking and management strategies within individual LTRZs but also other regulations for different types of fisheries in the area (i.e. recreational fisheries). Regulations should be implemented widely at the QMA level, and more specifically within individual LTRZs. The following options are recommended:

- ***That existing sanctuaries be maintained***
- ***New sanctuaries be considered in high priority areas.***
- ***Yearly review of lake trout quotas that consider progress towards rehabilitation objectives.***
- ***Alternative gear configurations and deployment methods that minimize incidental catch of lake trout should be encouraged and enforced.***
- ***The use of live capture gear (trap nets) should be encouraged throughout the lake by:***
    1. ***Exploring the concept of enhanced whitefish quotas for fisheries using live capture gear***
    2. ***Exploring the use of economic incentives such as preferential royalty rates for live capture gear types***
- ***In low priority LTRZs, the use of both commercial gear types can continue, but only in the presence of additional regulatory controls.***
- ***Implement a closed commercial fishing season from September 30th to December 1st***
- ***Consider seasonal exclusions from areas where lake trout spawn.***

STRATEGIES FOR THE CONSERVATION OF REMNANT STOCKS

Two Lake Huron lake trout stocks avoided extirpation, one in Parry Sound, the other in Iroquois Bay. Both populations were located in relatively isolated bays. It appears that this remoteness from the main lake may have protected these remnant populations from sea lamprey predation (Berst and Spangler 1973). Additionally, neither population was exposed to intense commercial fishing activity. Conservation strategies for these two remnant stocks fall into two broad categories: stocking these strains in other areas of the lake and protecting them in their native habitat.

These two remnant stocks are very important to rehabilitation efforts because they are indigenous to Lake Huron and are thought to possess local adaptations. Given their importance to lake trout rehabilitation, brood stocks have been developed from both populations. These strains are currently being stocked in a number of LTRZs throughout the North Channel and Georgian Bay.

There is a long history of rehabilitation in Parry Sound. These rehabilitation efforts have focused on excluding commercial fishing activity, minimizing recreational fishing mortality and stocking. As a result of these efforts, this population is currently classified as rehabilitated and

stocking within Parry Sound proper no longer occurs. Current management includes the maintenance of strict exploitation controls and monitoring the status of the population.

In Iroquois Bay there has also been a long history of rehabilitation efforts that include no commercial fishing activity, restrictive recreational fishing regulations and stocking of Iroquois Bay strain lake trout. However, assessments indicate that recovery of the lake trout population has not occurred as in Parry Sound. In response, even more restrictive recreational fishing regulations have been implemented, but full recovery does not appear to be imminent. A complete closure of the recreational fishery may be necessary.

From the Parry Sound and Iroquois Bay experiences, conservation strategies for remnant stocks are limited to developing brood stock for rehabilitative stocking and minimizing, or even eliminating, fishing mortality from both commercial and recreational sources.

Recommendations

Both Parry Sound and Iroquois Bay have been classified as active, high priority LTRZs. It is recommended that:

- ***Parry Sound and Iroquois Bay be managed in a highly conservative manner***
- ***No exploitation be allowed in Iroquois Bay until the mid-term objective has been achieved.***

PROGRESS EVALUATION

Integral to the lake trout rehabilitation process is a means by which to evaluate progress towards the short-term, mid-term and long-term objectives. The original lake trout rehabilitation plan for Ontario (OMNR 1996) provided eight evaluation criteria to measure progress such as total annual mortality, rates of natural reproduction and spawning stock size. However, in many cases, these criteria were too general, and in practical terms, difficult to measure and quantify. This section is intended to review the existing evaluation criteria and recommend new approaches where appropriate, as well as make recommendations for standardized assessment methodology.

Evaluation Criteria

Evaluation criteria are measurable quantities or biometrics that can be used to gauge progress towards rehabilitation objectives (Ebener 1998). A number of different criteria have been suggested by various authors (Hansen et al. 1995; OMNR 1996; Ebener 1998; McClain 2002) many of which have been used in the evaluation of lake trout rehabilitation in Lake Huron.

Age Structure

The 1996 Plan identified key attributes of the age structure of the population as potential evaluation criteria. It suggested that the age structure should be multi-aged with the mean age of the spawning population at least one year older than the mean age of first maturity. These conditions continue to be important evaluation criteria that are easily calculated and provide a clear indication of progress towards rehabilitation.

While originally presented as a single criterion, 'Age Structure', it is clear that this included two distinct criteria: multiple ages should be present in the population, and a substantial proportion of the population should be mature and contributing to the reproductive potential of the population.

The scientific literature indicates with increasing frequency that fish populations exhibiting numerous age classes are more resilient than those with fewer age classes (Richards and Rago 1999; Berkeley et al. 2004). In addition, it has been suggested that the age structure of a population reflects the magnitude of total mortality on the population (Devries and Frie 1996). As well, the value of a broad age distribution with respect to the reproductive capacity of a population has become increasingly clear in recent years (Berkeley et al. 2004; Froese 2004). Specifically, Berkeley et al. (2004) suggest a diverse age structure with adequate representation of old age classes is necessary in long-lived Pacific ground fishes due to highly variable recruitment across wide spatial scales. Berkeley at al. (2004) generally concluded that longevity is an adaptation, or a form of 'bet hedging', in environments where favourable conditions for reproduction are infrequent. In fact, Eshenroder et al. (1995*b*) suggested that the longevity of lake trout in large water bodies is an adaptation for the variable environmental conditions that frequently occur in those ecosystems. In this light it is suggested that at least seven age classes, older than ages four or five (the age when full recruitment to assessment gear occurs), be represented in lake trout populations around Lake Huron. As lake trout generally mature

between ages six and eight, representation of seven age classes in an assessed population would indicate the presence of numerous, mature cohorts in a population meeting this target.

Evidence also continues to accumulate for many species that larger, older females consistently produce larger eggs and contribute more to subsequent year classes than smaller females (Berkeley et al. 2004). Fecundity analysis for lake trout indicates that larger, older females produce more and larger eggs (Eschemeyer 1955; Peck 1988; O'Gorman et al. 1998; Bronte et al. 2007) and it is expected that larger, older female lake trout will contribute disproportionately more to subsequent production of juveniles. Additionally, older fish have been shown to be more effective spawners, spawning in more appropriate locations and at times that would maximize the chance of survival of their offspring (Francis et al. 2007). This would suggest that the older the mean age of the spawning population relative to the mean age to maturity, the better. More specifically, it is recommended that the criteria of the mean age of the spawning population being one year older than the mean age to maturity be considered an absolute minimum. Froese (2004) espouses this type of approach as one that is simple and easily understood. It is felt that the presence of older, more fecund individuals is imperative to the re-establishment and persistence of lake trout in Lake Huron.

Regardless of how spawning stock age structure is estimated, it should be stated that the age structure criteria and annual mortality estimates should also be predicated upon an adequate stock size (see spawning stock size criteria below). For instance, if the population is composed of only dozens of adult fish, the presence of a spawning stock would not be indicated even if the age distribution appeared satisfactory.

Lastly, it is recommended that the age structure of the population be considered one of the primary evaluation criteria used to assess progress towards lake trout rehabilitation across all three objectives. The age structure of the population reflects total annual mortality and without a broad age structure, it is unlikely that a sufficiently large spawning stock exists to satisfy even the short-term objective of lake trout rehabilitation.

Recommendations

It is recommended that the original age structure criteria be considered as two distinct criteria:

- ***The population should be multi-aged with a minimum of seven year classes present older than age four.***
- ***The mean age of the spawning population should be at least one year older than the mean age to maturity. This should be considered an absolute minimum.***

Lake Trout Survival/Mortality

The 1996 lake trout rehabilitation plan recommended that mortality of adult lake trout should not exceed 40% per year. This upper threshold continues to be a relevant evaluation criterion, although estimating mortality is often difficult, particularly if post-stocking survival is in question.

If catch curves are used to estimate total annual mortality (Ricker 1975), it is recommended that no fewer than five, fully recruited age classes be included in the analysis as unreliable estimates of mortality are otherwise generated. Using modelled approaches, Reid et al. (2001) suggested that the ratio of fishing mortality (F) to natural mortality (M) may be a more appropriate indicator of excessive mortality in some situations. This ratio should be between 1.2 -1.5, ratios above 1.5 would suggest that fishing mortality is excessive. However, it is unlikely that sufficient data exist in many LTRZs to accurately estimate both fishing mortality and natural mortality.

Finally, the near complete absence of older fish, manifested as a persistently truncated age distribution (e.g. few or no fish older than 5 or 6 years of age) despite a long stocking history, should be considered the ultimate indicator of excessive adult mortality, regardless of estimates generated from catch curves or F:M ratios. In these situations, estimates from either of these methods would be highly suspect and should be interpreted with caution.

Recommendations

Total annual mortality is fundamental to lake trout rehabilitation and should be monitored in all rehabilitation areas. It is recommended that:

- ***Total annual mortality not exceed 40% in active rehabilitation zones.***
- ***A minimum of 5 year classes be used for estimating mortality from catch curves (Ricker 1975).***
- ***Where F and M can be estimated, the F to M ratio should be in the range of 1.2 to 1.5. If this ratio exceeds 1.5, fishing mortality should be reduced.***
- ***Interpret catch curves and F:M ratios with caution if the age distribution is persistently truncated.***

Spawning Stock Size

The 1996 lake trout rehabilitation plan suggested that the CPUE of spawning lake trout in overnight gill net sets should be used as the sole indicator of spawning stock size. The recommended CPUE proposed was 17 to 65 spawning lake trout per 305m of large mesh gill net, which was thought to reflect a sufficiently large spawning stock. This recommendation is based on the findings of Segelby et al. (1995). While this criterion continues to be a viable indicator of spawner density, it is not the only indicator or criterion that could be used to estimate spawning stock size.

Similar estimates of spawning stock size can be obtained from age structured models such as cohort analysis or statistical catch at age (SCAA) models where sufficient data exist (Quinn and Deriso 1999). This method assumes that all fish beyond the age to maturity are contributing to the spawning population. However, in most LTRZs sufficient data may not available to develop SCAA models. In some cases reasonable estimates of spawning stock size could be calculated from the age structure of the population and estimates of annual mortality.

Another advantage of catch at age and SCAA models is that other metrics of reproductive potential such as spawning potential ratio (SPR) can be calculated (Goodyear 1993). SPR can be used to evaluate whether or not mortality is negatively impacting spawning stocks and overall population abundance. SPR should range from 0.2 to 0.6 (Clark 1991, 2002). The Lake Huron Technical Committee (LHTC) has recommended a minimum SPR value of 0.33. It is suggested that this approach be explored in LTRZs in Ontario waters where sufficient data exist (Ebener et al. 2005).

Alternatively, adult spawning stock size can also be estimated using non-lethal techniques such as trap nets, short-set gill nets, and mark-recapture methods. Data from various LTRZs where trap netting and short set gill nets have been used suggests that a trap net CPUE of at least 12-14 lake trout per trap net night, or a CPUE of 1.3 lake trout per hour in short set gill nets should indicate a sufficiently large spawning stock. Trap nets and a mark-recapture approach were used in Parry Sound to estimate adult stock size and various population parameters (Reid et al 2001). Although field programs utilizing these assessment methods may require a significant investment of manpower and resources, they may be the only option available in areas where lethal sampling is a concern.

Regardless of how spawning stock size is estimated, it should be reiterated that efforts to estimate spawning stock parameters should be predicated on attainment of the age structure criteria and low annual mortality. For instance, if the population is not multi-aged and the mean age of the spawning population is not older than the age of maturity, the presence of a spawning stock would not be expected.

Recommendations

This evaluation criterion is important in LTRZs where a spawning stock is expected. It is recommended that the following evaluation criteria be used:

- ***Average catch rates in excess of 17 spawning lake trout / 305m of large mesh gill net.***
- ***Minimum catch rates of 12 adult lake trout / net night in trap nets.***
- ***Minimum catch rates of 1.3 adult lake trout / hour in short set gill nets.***
- ***Use age structured models to estimate spawning stock size where sufficient data exists***
- ***Where data exist, SPR should be calculated and maintained above 0.33***
- ***Mark-recapture methods for estimating spawning stock size should be considered.***

Natural Reproduction

The 1996 Plan noted that the proportion of unclipped fish observed in a LTRZ should increase during rehabilitation. The 1996 Plan recommended that when 50% of age-two fish observed in a LTRZ were unclipped, stocking should be reduced or terminated. The proportion of unclipped fish in the population continues to be one of the key criteria by which lake trout rehabilitation can be assessed. However, the original benchmark proposed in the 1996 Plan targets an age (two year olds) that is infrequently encountered in typical field programs and does not provide any

guidance with respect to sample size or number of observations. For example, a single net with two, two year old lake trout, one clipped, one unclipped, would satisfy the requirement even if the LTRZ was far from rehabilitated.

Ebener (1998) suggested that an average catch of 1 or 2 wild juvenile lake trout per 305 m (1000 ft) of gill net should be used as an indicator of successful reproduction and recruitment to the population. CPUE of unclipped juveniles from both Parry Sound and South Bay gill netting projects are comparable to those recommended by Ebener (1998). These results suggest that this criterion is applicable in Ontario waters given that these two LTRZs are rehabilitated, or close to rehabilitated in the case of South Bay.

Additionally, the 1996 Plan recommended changes to stocking based on the catches of a single age class. As an alternative to using a single age class that may not be observed regularly, it is proposed that the total percentage of all unclipped fish be considered (regardless of age) and that at least three consecutive years be included in the calculation. The Lake Huron lake trout rehabilitation guide (Ebener 1998) recommended reducing stocking when wild lake trout made up 25% of the mature portion of the population over a three to five year period. In this light, when 25% of the population in a LTRZ is unclipped, stocking plans should be at least reviewed, and adjusted accordingly. When 50% of a 'significantly large' population in a LTRZ is unclipped over three consecutive years, stocking should be terminated to avoid negative interactions between wild and stocked juveniles.

Recommendations

Measures of natural reproduction (wild fish) are a very useful evaluation criterion and should continue to be used. Three measures are recommended as follows:

- ***Catches of 2 or more unclipped juvenile fish per standard index net indicate successful reproduction and natural recruitment.***
- ***When 25% of the population is unclipped stocking plans should be reviewed.***
- ***Stocking should be terminated once 50% of a significantly large population is unclipped in three consecutive netting surveys.***

Abundance

The 1996 lake trout rehabilitation plan noted that lake trout abundance should increase as rehabilitation progressed. However, the original recommendation provided no guidance on how to quantify progress towards this goal, particularly with respect to the abundance of various segments of the population.

Spawning stock size and the abundance of wild juveniles are addressed by other evaluation criteria. As a result, 'Abundance' may more appropriately be interpreted as the abundance of fish (of all ages) that are fully recruited to index fishing gear, but are not actively engaged in spawning.

A number of methodologies have been successfully implemented in the spring or early summer to target non-spawning lake trout. These have included large-mesh or multi-mesh gill netting, summer trap netting, creel surveys, small-mesh short-set gill netting, and commercial fisheries assessment. Given the diversity of methods, comparison between projects is difficult, if not impossible. Abundance estimates from commercial and recreational fisheries tend to be particularly problematic because they often target a specific portion of the population, and as a result are not representative of the entire population. Independent assessment programs using standardized, graded-mesh gill nets avoid many of these problems, although lethal sampling should be carefully considered in LTRZs with sensitive lake trout populations (e.g. Iroquois Bay). Additionally, independent assessment programs in Ontario waters have a long time series and have been employed throughout most of the lake, providing a strong benchmark against which changes in lake trout abundance can be compared. It is recommended that the existing independent index netting protocol be utilized in either the spring or early summer to assess the abundance of non-spawning lake trout.

Recommendations

- ***'Abundance' should be re-defined as 'abundance of non-spawning-phase lake trout'***
- ***An abundance estimate should be derived from either spring or summer assessment programs using graded-mesh gill nets.***
- ***CPUE of 8-10 or more lake trout per offshore index net should be considered an indicator of sufficient densities of lake trout to satisfy the short term rehabilitation objective.***
- ***Catch rates in the commercial and recreational fisheries should not be used as specific abundance criteria, although they can provide general trend information and indicate the need to initiate an independent assessment survey.***

Yield

The 1996 Plan identified total lake wide yield as the ultimate goal of rehabilitation, stating that yield should continue to increase to 1.12 million kilograms per year (0.20 kg per ha) as per the FCOs (Desjardine 1996). The original plan recognized that yield is not an appropriate measure of progress during the early stages of rehabilitation. This is supported by the experience in the Canadian waters of Lake Huron where LTRZs with the highest yields have generally shown the least progress toward rehabilitation.

Furthermore, given the revised long-term objective for lake trout rehabilitation, establishing self-sustaining populations with stable spawning stocks, constant natural recruitment and low annual mortality, yield is not an appropriate measure of rehabilitation success for individual LTRZs.

Recommendations

- ***Yield should not be maintained as an evaluation criterion.***

Egg Deposition

The 1996 Plan recommended that the density of eggs on spawning substrate could be used as evaluation criteria. That report recommended densities in the range of 25-500 eggs per m^2. While this criterion has intuitive appeal and could be used to verify the presence of a sufficiently large spawning stock, in practice it is very difficult to implement. Measuring egg deposition is logistically demanding and requires ideal conditions. Additionally, small changes in the spatial location of spawning aggregations from year to year could also make this benchmark too variable to reflect meaningful changes in spawning stock biomass or as a potential indicator of expected recruitment. Finally, egg deposition rates are unlikely to reflect stressors that are ultimately inhibiting lake trout rehabilitation on Lake Huron such as inadequate stocking densities and excessive adult mortality.

Recommendations

- ***Egg deposition should not be maintained as an evaluation criterion.***

Range

The 1996 lake trout rehabilitation plan stated that the movement of lake trout from primary rehabilitation areas would result in a gradual in-filling of surrounding waters, expanding the effective area under rehabilitation. While it is likely that lake trout move beyond the boundaries of LTRZs, it is unclear how this movement should be quantified, especially with respect to the lake trout rehabilitation objectives. Lake trout movement should continue to be monitored through the recovery of CWTs, but movement or range should not be considered a measurable criterion to gauge progress towards rehabilitation.

Recommendations

- ***Movement or range should not be maintained as an evaluation criterion.***

ASSESSMENT TACTICS

Lake trout rehabilitation is expected to follow a progression from development of a population and subsequent spawning stock using stocked fish, to production of wild fish through natural reproduction by stocked adults, to a population that is entirely self sustaining. Following this progression through rehabilitation, field programs and assessment tactics need to be tailored to reflect the expected state of rehabilitation within individual LTRZs. For example, LTRZs that have yet to meet the short-term objective should be monitored with field programs that will provide key information on the age structure of the developing population. From age structure data, inferences can be drawn regarding the potential presence of a spawning population, and if a spawning stock is expected to be present, field programs can focus on estimating the spawning stock size.

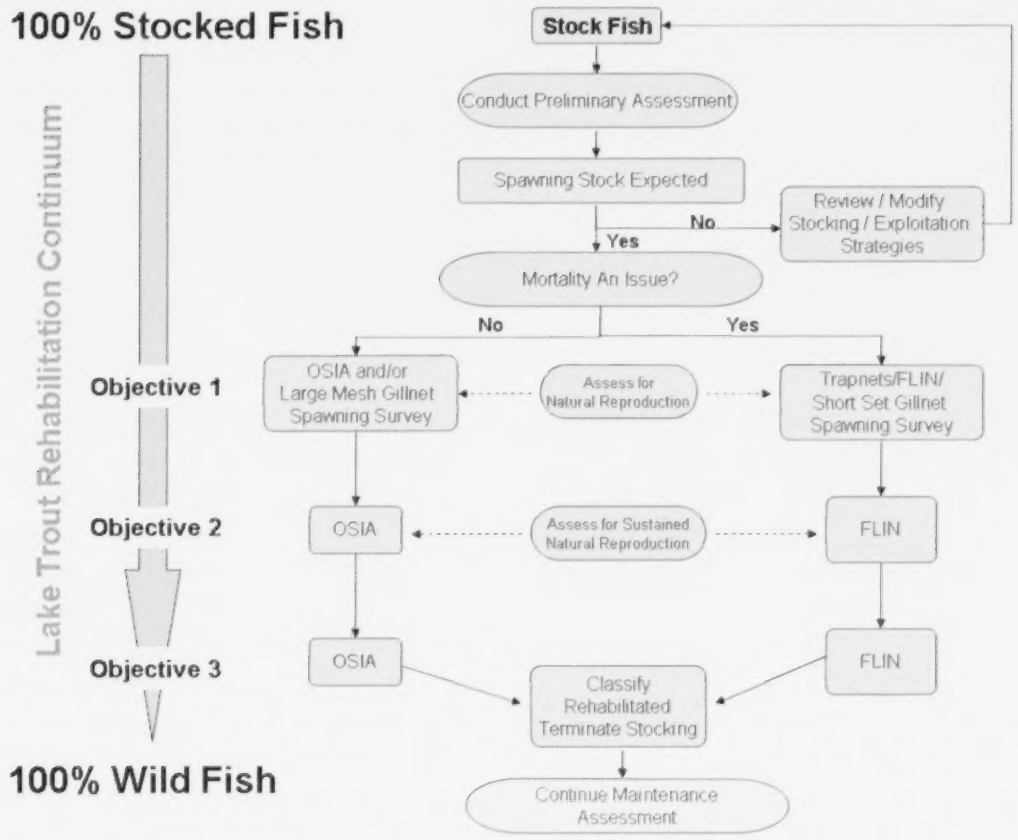
To provide preliminary perspective for evaluating progress towards lake trout rehabilitation after stocking programs have started, initial assessment projects should provide general information to determine if stocked fish have survived and if the formation of a spawning stock is expected. Of primary importance for these initial data needs across most LTRZs, has been the on-board commercial catch sampling (CF) and the long term fisheries independent offshore index gillnet assessment (OSIA) programs implemented by the UGLMU. These two project types have been instrumental in providing initial, background data regarding the status of lake trout in many LTRZs. It is expected that these two project types will continue to be very important for evaluating progress in the future.

Following the collection of general information (after stocking has been initiated) through the CF and OSIA programs, evaluation of progress towards each of the three objectives requires fisheries independent surveys focusing on each objective. One of the primary considerations when planning for these surveys is the need to consider if mortality of captured lake trout is an issue. Mortality is of special concern in LTRZs with remnant stocks (Parry Sound and Iroquois Bay) but is also a concern in LTRZs where natural reproduction is occurring and wild spawning stocks are building. Lake trout populations at this stage of rehabilitation are particularly sensitive to adult mortality and lethal assessment methodologies should be avoided in this situation. This is presently the case in Owen Sound and South Bay. However, lake trout populations in LTRZs with large stocking programs may be able to endure the levels of mortality observed in assessment programs using overnight gill net sets.

Past lake trout assessments have been conducted using a range of lethal and non-lethal protocols and gear types including the OSIA protocol, trap nets, short set, small mesh gillnets and overnight sets of large mesh gillnets on spawning shoals. Additionally, fall implementation of the Spring Littoral Index Netting (SLIN) protocol (Hicks 1999) has been used and coined 'FLIN' surveys. In the rehabilitation review it became evident that a limited suite of the assessment protocols and gears, amongst those implemented by the UGLMU, delivered the needed information. Some of the assessment protocols also avoided mortality where it was a concern. This limited suite protocols and gear types are proposed for future assessment efforts (Figure 22). It is expected that future lake trout assessment efforts can be standardized using the suggested approach (Figure 22). Specifics for each of the suggested protocols are included in Appendix 3. Although the suggested, standardized assessment approach is very important to

future evaluations, of primary importance is that field programs collect data that support evaluation criteria and subsequently allow assessment of progress towards specific rehabilitation objectives.

Figure 22. Decision tree for UGLMU lake trout assessment projects.



Recommendations

- ***Assessment tactics should be specific to each of the rehabilitation objectives.***
- ***An assessment plan needs to be developed for each LTRZ and implemented according to the priority rankings (see Table 2)***
- ***Field gear and protocols should be standardized (see Figure 22).***
- ***Non-lethal tactics should be used in LTRZs with remnant stocks or LTRZs exhibiting increasing levels of natural reproduction***

HABITAT

Habitat is not explicitly captured in any of the three rehabilitation objectives, but plays a pivotal role in rehabilitation. Specific to Lake Huron, open water and spawning habitat is not thought to be limiting at this time. The continued survival and growth of stocked lake trout supports the notion that the open water habitat of Lake Huron can support and sustain substantial populations of lake trout. Where spawning populations of pure-strain lake trout have developed, natural reproduction has generally occurred, suggesting that suitable spawning habitat continues to exist. However, reductions in lake levels in recent years may have an impact on the habitat available for shallow spawning lake trout. In addition, the proliferation of invasive species such as zebra and quagga mussels (*Dreissena polymopha* and *Dreissena bugensis*), round gobies (*Neogobius melanostomus*) and rusty crayfish (*Orconectes rusticus*) on lake trout spawning shoals has raised concern regarding impacts on lake trout reproduction.

Although the availability of spawning substrates is not limiting in most of Lake Huron (Ebener 1998), field observations in areas of abundant habitat suggest fish utilize discrete areas for spawning and that the location of these areas may change from one year to the next (UGMLU unpublished data). It is unclear why these discrete locations are chosen in large areas of seemingly suitable habitat (Gunn 1995). As a result of the uncertainty around site selection by spawning fish, the incremental loss of habitat in certain portions of Lake Huron through shoreline development may have unknown, negative impacts on the reproductive capacity of lake trout and consequences for lake trout rehabilitation.

Recommendations

- ***Document and protect lake trout spawning sites, or sites with suitable spawning habitat, throughout Lake Huron.***

COMMUNITY INTERACTIONS

As a post glacial, colonizing species, lake trout are most frequently found in simple fish communities. Martin and Olver (1980) noted that outside of the Great Lakes, only 19 other fish species naturally occur in water bodies with lake trout. In the Great Lakes, lake trout were historically associated with coregonines, (lake whitefish, lake herring, and deepwater ciscoes), burbot (*Lota lota*), and sculpin species (*Cottus sp.*) (Christie et al. 1987). Today, numerous exotic species exist in the Great Lakes and this has had consequences for lake trout rehabilitation. In Lake Huron, the exotic species that are thought to have the most impact on lake trout include the sea lamprey and alewife (*Alosa pseudoharengus*).

Sea Lamprey

Sea lamprey were first documented in Lake Huron in 1937, although their discovery in Lake Michigan in 1936 suggests that they were present in Lake Huron at least a year earlier (Hansen 1999). Sea lamprey predation has been identified as a significant cause of mortality for lake trout in most areas of Lake Huron (Johnson and VanAmberg 1995; Sitar et al. 1999) and continues to be regarded as a significant impediment to lake trout rehabilitation (Eshenroder et al. 1995*a*; Ebener 1998; Sitar et al. 1999). For example, Swink (1990) found that lake trout between 18.5 and 22" (47-55.9 cm) have only a 35% chance of surviving a lamprey attack. In the North Channel and northern main basin, lamprey-induced lake trout mortality has been so severe at times, that few fish survive past age six (Eshenroder et al. 1995*a*; Wilberg et al. 2003). The degree of lamprey wounding and associated mortality is lower in the central and southern parts of the main basin and Georgian Bay, but even there, lamprey-induced mortality has been estimated to be considerably higher than both fishing and natural mortality (Sitar et al. 1999).

Sea lamprey-induced mortality is particularly detrimental for lake trout rehabilitation since lamprey tend to select larger individuals (Farmer and Beamish 1973). As such, lamprey-induced mortality is borne mostly by the spawning population, potentially reducing the reproductive capacity of the stock (Sitar et al. 1999). Hansen (1999) noted that lake trout populations in the Great Lakes will probably be able to rebuild in the face of either limited fishing mortality or controlled sea lamprey induced mortality, but the combined effect of both mortality sources is sufficient to prevent rehabilitation.

Recommendations

- ***Continue to advocate for control programs that reduce sea lamprey abundance and ensure that marking rates are below the GLFC target of five wounds per 100 lake trout.***
- ***Continue to contribute to the sea lamprey assessment program by measuring marking rates in Ontario waters of Lake Huron using standardized wound recording methods.***

Prey Species

Historically, the diet of lake trout consisted largely of lake herring, deepwater ciscoes and sculpin species (*Cottus sp.*) (Dyer et al. 1965; Christie et al. 1987; Conner et al. 1993; Owens and Bergstedt 1994). These diet items still provide a significant portion of lake trout diets in some parts of Lake Superior (Conner et al. 1993) and are consumed by lake trout in the other Great Lakes when they are available (Miller and Holey, 1992). More recent studies indicate that lake trout feed heavily on alewives, and to a lesser extent smelt, in the lower Great Lakes and tend to have a more diverse diet than non-native salmonids (Eck and Wells 1987; Jude et al. 1987; Stewart and Ibarra, 1991). Stocked lake trout have demonstrated a reluctance to switch away from non-native prey species, even when native food items are considerably more abundant (Eck and Wells 1987; Jude et al. 1987). This reluctance has led some authors to speculate that non-native prey are simply easier to catch than coregonine and sculpin species (Eck and Wells 1987) or that stocked lake trout forage more in the pelagic zone than native fish did historically.

The dependence on alewives in particular has significant implications for lake trout restoration in Lake Huron. Alewives have been associated with Thiamine Deficiency Complex (TDC), a reproductive impairment that often results in significant mortality (up to 100%) of developing lake trout embryos (Fisher et al. 1996) (see TDC section below). However, the recent collapse of alewives in Lake Huron provides a unique opportunity to examine changes in the status of TDC related measures with the concurrent declines in alewife consumption by lake trout in Lake Huron (Bence et al. 2008). Furthermore, Madenjian et al. (1998) and Mason et al. (1998) suggested that growth and maturity of lake trout could be slowed if larger diet items (e.g. lake herring or deepwater ciscoes) were not available for mature lake trout. Delayed maturity and smaller mean size of mature fish could prevent the establishment of a sufficiently large spawning stock required for sustained natural reproduction (Conner et al. 1993).

Recommendations

Given the impacts of exotic prey species and the importance of lake herring to lake trout recovery, we recommend the following:

- ***Facilitate the suppression of exotic prey species.***
- ***Encourage the recovery of lake herring and deepwater ciscoes throughout Lake Huron.***

Critical Life Stages

The absence of significant natural recruitment in many parts of the Great Lakes despite the successful survival and establishment of large spawning stocks of hatchery reared fish, has lead some scientists to suggest that interactions during critical life stages are the single largest impediment to lake trout rehabilitation (Krueger et al. 1995b; Fitzsimons et al. 2002). In some LTRZs in Ontario waters, natural recruitment has been detected. The reasons for these increases in recruitment have been attributed to the presence of a remnant stock, absence of commercial fisheries, restrictive recreational fishery regulations and reduced sea lamprey wounding rates. However, despite these possible explanations the recent lake wide collapse of alewives (Bence et

al 2008) provides additional clarity regarding the impacts of alewives on early life stages of lake trout

On Six Fathom Bank, a mature spawning stock of lake trout had developed by the mid 1990s (Madenjian et al 2004). Furthermore, the beam trawling by Desorcie and Bowen (2003) did detect wild lake trout fry on Six Fathom Bank as early as the spring of 1994. However, these wild lake trout fry caught during 1994 never recruited to the gill nets set on Six Fathom Bank as part of the spring and fall surveys conducted by the USFWS and USGS during 1995-2003 (Madenjian et al 2004). This apparent lack of survival was in the presence of an abundant alewife population.

With the collapse of alewives in 2004, recruitment of wild lake trout to assessment gear on Six Fathom Bank has increased substantially (Chuck Madenjian, USGS, pers. comm.). This increase in lake trout natural reproduction in the absence of alewives has also been noted in bottom trawls conducted in the main basin by the USGS (Riley et al 2007) and more recently in the Drummond Island Refuge (Mark Ebener, CORA, pers. comm.). These data suggest alewife consumption of lake trout fry, described by Kruger et al (1995*b*) and O'Gorman et al (2000) in Lake Ontario, was having a much larger impact than expected on lake trout rehabilitation. Madenjian et al (2008) discuss this phenomenon across the Great Lakes and suggest that consumption of lake trout fry by alewives is a primary impediment to rehabilitation. Recent data from Lake Huron would seem to confirm this.

In addition to the perceived impacts of alewives, the recent establishment of round goby (*Neogobius melanostomus*) may have significant consequences for natural reproduction. For instance, round gobies have been observed foraging heavily on lake trout eggs in a laboratory environment (Chotkowski and Marsden 1999). However the magnitude of this effect in the wild is unclear.

Recommendations

- ***Evaluate rates of lake trout natural reproduction in the absence of alewives***
- ***Evaluate the effects of round goby predation on natural reproduction of lake trout***

Thiamine Deficiency Complex

Reproductive impairment was identified as a problem early in the lake trout rehabilitation efforts on the Great Lakes, although it was not until the early 1990s that mortality rates of lake trout in the hatchery environment escalated to more than 50% (Honeyfield et al. 1998). Early efforts to elucidate a cause and effect relationship for this affliction, now labelled TDC, focused on environmental contaminants but by the mid-1990s it became clear that TDC was associated with the consumption of non-native forage species, particularly alewives (Fitzsimons and Brown 1998). TDC appeared to be most pronounced in populations from Lake Ontario where alewives were the main forage species, while TDC did not occur in lake trout from Lake Superior where alewives were absent, or very rare (Fitzsimons and Brown 1998).

Fitzsimons (1995) and Fisher et al. (1996) considered the possibility that TDC was associated with nutritional deficiencies rather than contaminant burden, and that the causative agent of TDC was thiaminase, an enzyme present in large amounts in the digestive tracts of alewives. The association of TDC with an alewife diet has lead management agencies to reconsider their lake trout rehabilitation strategies. Some reports have stated that replacement of alewives with native forage species such as lake herring, deepwater chub, yellow perch and shiner species (Cyrpinidae family) is extremely important if lake trout rehabilitation is to succeed (Fitzsimons et al. 1998). However, the recent collapse of alewives in Lake Huron followed by a surge in lake trout natural reproduction has given researchers cause to re-evaluate the impacts of TDC and suggest that predation by alewives on lake trout fry may have been a more significant impediment (Bence et al. 2008; Madenjian et al 2008). Continued monitoring of TDC indicators may help clarify the importance of either effect. If TDC continues to be a problem, it has been suggested that some of the current benchmarks associated with spawning stock size may be too low, in which case more spawners may be necessary if embryo mortality is significantly higher than originally estimated.

Recommendations

- ***Encourage the recovery of native prey species, especially lake herring***
- ***Facilitate the suppression of alewives in Lake Huron***
- ***Monitor the prevalence of TDC through yearly egg collections from spawning populations.***

RESEARCH

Given the changes in the Lake Huron ecosystem over the last century, research continues to play an important role in lake trout rehabilitation. Recent perturbations continue to increase uncertainty surrounding lake trout rehabilitation and have raised a number of key questions. It is the role of research to address these questions, which generally fall into several broad categories. These include the impacts of invasive species, changes in the prey community, habitat issues, and uncertainties regarding management decisions which stem from ecosystem change.

Exotic species in the Great Lakes have had significant detrimental effects on lake trout beginning with the establishment of sea lampreys and alewives. The influx of new exotics such as round goby and the rusty crayfish (*Orconectes rusticus*) continue to influence lake trout in the Great Lakes and complicate rehabilitation efforts. For example, it has been suggested that these exotics are likely to impede natural reproduction through predation on eggs and early life stages (Chotkowski and Marsden 1999). Research is needed to quantify these impacts and gain understanding regarding the implications for lake trout rehabilitation on Lake Huron.

Related to the invasion of exotic species, major changes in the prey species consumed by lake trout have occurred in Lake Huron. Up to 2003, alewives were extremely abundant in Lake Huron, forming the bulk of prey biomass and were the dominant item in the diet of lake trout (UGLMU unpublished data). After 2003, alewives virtually disappeared from Lake Huron, and are currently found only rarely in the stomachs of predators. This has important implications for lake trout rehabilitation given that the consumption of alewives has been directly linked with TDC in lake trout (Fitzsimons and Brown 1998) and with predation on lake trout fry (Madenjian et al 2008). Additionally, the impacts of the loss of alewives as the dominant prey item in lake trout diets is unknown. One consequence of the loss of alewives is the subsequent paucity of large-bodied prey fish in the offshore waters of Lake Huron, which appears to be contributing to lower asymptotic lengths and smaller mean weights at age, which in turn may be causing a reduction in fecundity of Lake Huron's mature female lake trout. (UGLMU unpublished data; MiDNR unpublished data).

Concomitant with the decline in alewives was a resurgence of a number of nearshore native forage species, most notably yellow perch, emerald shiners (*Notropis atherinoides*) and in some parts of the lake, lake herring (Fielder and Thomas 2006; Roseman et al 2006). It has been suggested that the resurgence of lake herring is particularly important for the rehabilitation of lake trout. Historically, lake herring were the dominant food item of lake trout and perhaps more importantly, reach body sizes that increase the foraging efficiency of large lake trout (Mason et al. 1998). This is expected to facilitate the growth of large, mature lake trout which are critical to the formation of stable spawning stocks (Conner et al. 1993). It is unclear why lake herring have recovered in some parts of Lake Huron and not others. Given the potential importance of lake herring to the rehabilitation of lake trout, research is needed to determine the impediments to lake-wide recovery of lake herring.

With respect to habitat, there continues to be uncertainty regarding spawning site selection and the spatial distribution of spawning aggregations from one year to the next. Ultimately, key

factors that influence the selection of spawning sites when appropriate habitat is abundant are currently unknown or poorly understood.

Lastly, there are a number of important management issues associated with lake trout rehabilitation that should be addressed through research. Prominent among these issues is uncertainty regarding management of lake trout in a multi-species context in the Lake Huron commercial fishery. Managing the different species captured in the Lake Huron commercial fishery is becoming an increasingly difficult task given their focus on lake whitefish in the fishery principally with, in Ontario waters, gill nets. Research focused on decision making in a multi-species fishery is becoming increasingly important on Lake Huron. Other management related research topics include uncertainties around calculation of mortality rates, the influence of life stage and stocking practices on successful rehabilitation, and verification and improvement of the criteria used to evaluate progress towards rehabilitation.

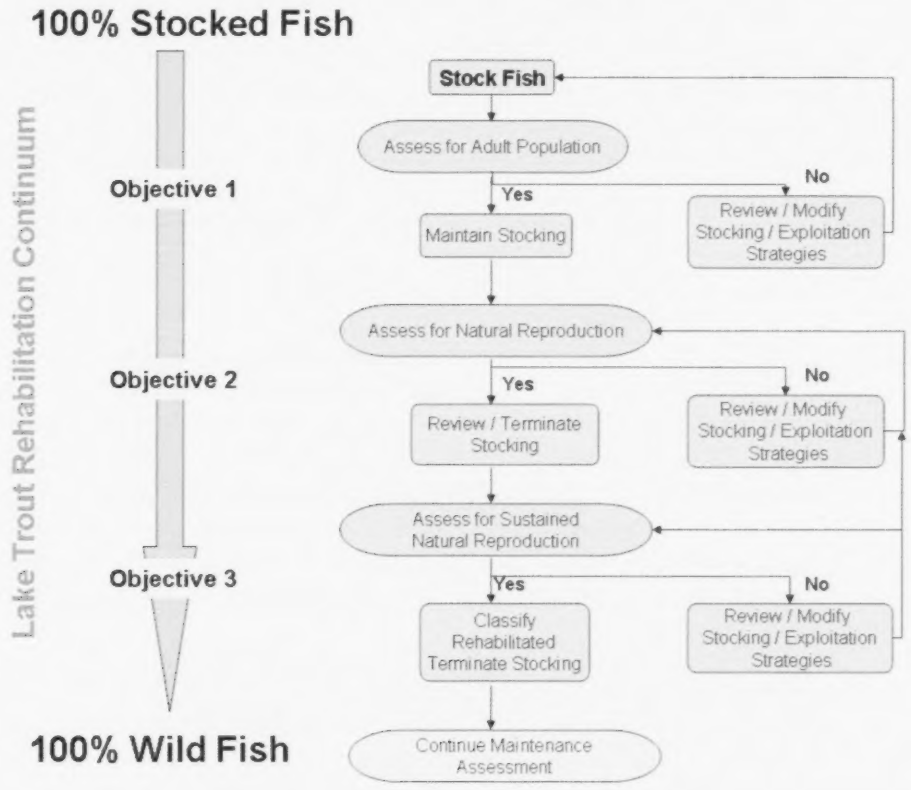
Recommendations

- ***Investigate the impacts of alewives along with other impediments such as fishing mortality and sea lamprey induced mortality to identify the most important impediment to lake trout rehabilitation.***
- ***Investigate whether round gobies, rusty crayfish and other exotics are inhibiting lake trout rehabilitation***
- ***Assist in the verification and improvement of rehabilitation criteria.***
- ***Identify impediments to lake-wide recovery of the native prey community, especially lake herring.***
- ***Identify the key attributes of spawning habitat that have been associated with natural reproduction and the characteristics that influence site selection by lake trout spawning stocks.***
- ***Investigate effective management models for multi-species fisheries in Lake Huron that incorporate lake trout rehabilitation needs.***
- ***Continue to investigate methods to accurately estimate mortality***
- ***Examine the influence of life stage and stocking practices on prevalence of natural reproduction, rather than just survival of stocked fish.***

DISCUSSION

A common theme discussed in many documents regarding lake trout rehabilitation is that of a progression or 'continuum' through rehabilitation. Lake trout rehabilitation is expected to follow a progression from development of a population and subsequent spawning stock using stocked fish, to production of wild fish through natural reproduction by stocked adults, to a population that is entirely self sustaining. This concept is fundamental to all discussions regarding sequential progress of lake trout rehabilitation and a flow chart that describes the decision making process through this continuum is presented in Figure 23.

Figure 23. Flowchart describing a management decision model and recommended actions as rehabilitation objectives are achieved.



The 1996 Lake Trout Rehabilitation Plan for Lake Huron (Canadian jurisdiction) identified an overall goal and three objectives for lake trout rehabilitation that followed this progression. This document also identified areas for focused rehabilitation efforts, called LTRZs, recommended strategies for stocking within these zones, and suggested a suite of evaluation criteria against which progress could be gauged.

The intent of the goal and objectives from the 1996 Plan continue to be relevant. However, revisions to the objectives have been recommended that more closely relate the three objectives

to the progression through rehabilitation. These revised objectives more closely reflect timelines associated with rehabilitation, and how these timelines differ between individual LTRZs as a result of differences in stocking history, stocking density, total annual mortality, and age to maturity. The most significant revision to the original objectives was to the long term objective which was originally lake-wide in scope and difficult to relate to individual LTRZs.

Using the 1996 Plan objectives and evaluation criteria as benchmarks, progress towards rehabilitation in each of the 16 LTRZs was described. With a few exceptions, age distributions were truncated in most LTRZs with few fish observed older than six years of age. This suggests that adult mortality is an impediment to rehabilitation in many parts of Lake Huron. However, where adult mortality has been controlled, signs of rehabilitation have been observed. For example, the Parry Sound remnant lake trout stock has been successfully rehabilitated and natural reproduction has been observed in both Owen Sound and South Bay.

Excessive adult mortality may not be the only impediment to lake trout rehabilitation. The Iroquois Bay remnant population has not recovered despite the implementation of restrictive management actions and there are a number of LTRZs that are located in areas with few sources of adult mortality. These include Grand Bank and the Limestones reef complex. Generally these areas have low lamprey abundance and little or no exploitation due to their distance offshore. However, rehabilitation has not progressed as expected given the lack of normal impediments. It is unclear why Iroquois Bay has not recovered, but for these other areas it is suspected that their remoteness has made stocking on top of lake trout spawning habitat difficult. In many cases fish were stocked large distances from spawning habitat.

The 1996 Plan presented a Rehabilitation Status and Protection Class classification system for the LTRZs that provided some guidance for stocking and exploitation control. However, this system failed to consider the probability of success in individual LTRZs and did not provide any direction for rehabilitation assessment. For example, there were ten active LTRZs assigned a secondary protection class, although the possibility for successful rehabilitation was not consistent among all of these. As an alternative, a priority ranking system has been presented which considers the presence of, or proximity to remnant stocks, evidence of natural reproduction, low lamprey abundance, and low exploitation. This priority ranking system will facilitate focused and more effective rehabilitation efforts in the future.

The 1996 Plan also identified a number of evaluation criteria that could be used to measure rehabilitation progress. However, it was unclear how some of these measures related to rehabilitation objectives. Additionally, several criteria were logistically impractical or were not consistent with UGMLU assessment programs or data sources. However, a number of key evaluation criteria were included in the 1996 Plan and continue to form the foundation for evaluating progress towards rehabilitation. These include age structure, total annual mortality, spawning stock size, and levels of natural reproduction.

The 1996 Plan did not discuss how data to support lake trout rehabilitation should be collected. Without well defined assessment tactics it was possible to run field programs that collected data that were not directly comparable between LTRZs or through time. As a result, it is recommended that a suite of standardized assessment tactics be employed whenever possible.

The appropriate assessment tactic needs to reflect the expected stage of rehabilitation in a LTRZ and the appropriate rehabilitation objective.

The Lake Huron fish community and ecosystem continue to change. These changes have implications for lake trout rehabilitation. Low water levels, continued lake-shore development, invasion of exotic species, and continued sea lamprey predation all have direct effects on lake trout. Additionally, in recent years there has been a marked shift in the prey fish community of Lake Huron, with the virtual disappearance of alewives and a resurgence of lake herring in some locations around the lake. The ramifications of these changes are uncertain at this time, highlighting the need for continued research.

Collectively, the recommendations presented here form the basis for a revised lake trout rehabilitation plan for the Canadian waters of Lake Huron. The revised plan will incorporate lessons learned since 1996 and will include individual stocking and assessment plans tailored to each LTRZ. In an effort to ensure that lake trout are stocked on the best available spawning habitat in each LTRZ, discreet stocking locations will be identified in the stocking plans. The revised lake trout rehabilitation plan will provide guidance for more focused and effective rehabilitation efforts in the future.

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APPENDIX 1

Lake trout stocking records for Canadian waters of Lake Huron, 1968 to 2006. Graphs depicting stocking in LTRZs 12, 14 and 16 are not displayed as stocking in these zones was minimal or non-existent.

Table 3. Lake trout stocking history for Canadian waters of Lake Huron from 1974 to 2006. Stocking numbers are yearling equivalents and include splake, backcross, and all lake trout strains planted in each LTRZ*.

	Lake Trout Rehabilitation Zone															
YEAR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15*	Total
1974	0	0	0	0	0		0	0	149 351	21 615	0	0	0	0	37 100	208 066
1975	0	0	0	0	0	98 500	0	0	0	0	0	0	0	0		98 500
1976	0	0	0	0	0	99 000	0	0	0	736	0	0	0	0	640	100 376
1977	0	0	0	0	0		0	0	46 028	0	0	0	18 000	0	30 000	94 028
1978	0	0	0	0	0		0	0	0	0	0	0	0	0	30 000	30 000
1979	0	0	180 698	0	4 600		0	0	290 599	312 192	0	0	0	0	30 000	818 089
1980	0	0	70 000	0	32 800		0	0	365 756	314 759	0	0	0	0	30 000	813 315
1981	0	0	88 500	0	24 460	55 333	0	0	254 866	242 023	0	0	0	0		665 182
1982	0	0	135 280	0	2 000	107 509	0	0	257 088	419 147	0	0	0	0	22 000	943 024
1983	0	0	115 014	0	3 000	60 000	0	0	234 914	388 690	0	0	0	0	29 994	831 612
1984	0	100 400	198 670	0	2 870	106 380	0	0	320 652	362 699	0	0	0	0	29 700	1 121 371
1985	0	94 400	205 702	0	3 095	80 464	0	0	317 291	298 642	0	0	0	0	29 529	1 029 123
1986	0	67 440	153 820	0	5 500	81 935	0	0	313 266	306 806	0	0	0	0	30 472	959 239
1987	0	236 720	177 649	0	3 123	69 889	0	0	260 191	297 632	0	0	0	0	30 100	1 075 304
1988	0	164 270	174 806	307 246	0	79 938	0	0	204 828	271 039	0	0	25 950	0	30 795	1 258 872
1989	0	153 146	202 741	170 079	5 250	20 000	0	0	329 330	267 143	0	0	35 118	0	32 085	1 214 892
1990	0	92 783	115 538	0	0	15 000	0	0	206 475	226 349	2 500	0	43 500	0	30 063	732 208
1991	0	153 895	155 191	0	0	20 550	0	0	190 862	277 371	0	0	73 034	0	18 656	889 559
1992	0	159 772	196 584	60 071	0	12 871	317 322	0	282 727	267 246	0	0	166 996	0	30 262	1 493 851
1993	0	237 194	121 800	66 508	0	44 105	0	179 884	212 962	238 088	64 892	0	207 220	0	14 782	1 387 435
1994	0	70 387	221 002	0	0	0	903 752	0	242 491	267 010	267 825	0	144 019	0	27 981	2 144 467
1995	0	157 911	133 451	81 820	6 396	27 883	0	0	173 891	212 424	374 699	0	351 693	0	44 975	1 565 143
1996	0	52 143	155 445	345 968	5 525	46 243	0	91 542	257 606	63 933	282 836	0	421 256	0	5 102	1 727 599
1997	0	98 134	138 597	234 163	3 148	31 637	277 767	0	311 493	131 114	526 947	0	195 416	0	9 998	1 958 414
1998	0	244 611	114 374	133 624	3 124	15 077	386 502	0	288 621	119 371	417 223	0	251 292	0	5 066	1 978 885
1999	0	190 702	99 045	97 119	4 500	5 081	529 500	0	431 698	176 936	331 277	0	228 969	0	14 022	2 108 849
2000	0	226 338	68 082	49 712	2 999	5 023	0	461 028	320 516	513 660	216 611	0	495 040	0	89 096	2 448 105
2001	0	190 186	62 636	154 868	3 023	5 021	0	273 762	348 703	275 992	176 464	0	214 201	0	67 688	1 772 544
2002	180 207	105 756	109 038	0	3 000	5 235	0	182 747	32 498	236 239	248 968	0		0	14 450	1 118 138
2003	0	168 335	69 209	196 078	3 444	5 087	319 541	0	319 454	198 285	258 235	0	272 656	0	9 425	1 819 749
2004	0	216 169	127 818	210 449	3 244	5 006	225 564	0	300 119	258 185	226 474	0	274 563	0	12 116	1 859 707
2005	0	208 627	94 290	0	3 221	5 355	90 874	0	269 907	296 506	150 525	0	280 573	0	11 794	1 411 672
2006	0	213 112	98 563	0	3 105	5 042	0	413 443	222 223	96 936	208 321	0	0	0	9 190	1 269 935

* - Stocking numbers presented for LTRZ 15 exclude those fish stocked into the main basin of Lake Huron, outside of South Bay proper.

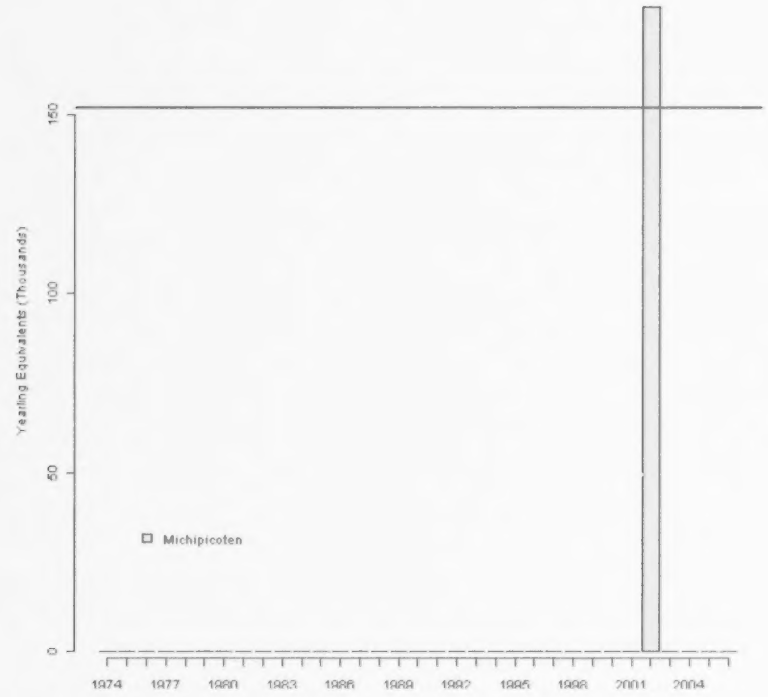

Figure 24. Stocking history for lake trout and backcross in LTRZ 1, Ontario waters only, 1974 to 2006. The horizontal line represents 2.5 yearlings/ha target for this rehabilitation zone (OMNR 1996).

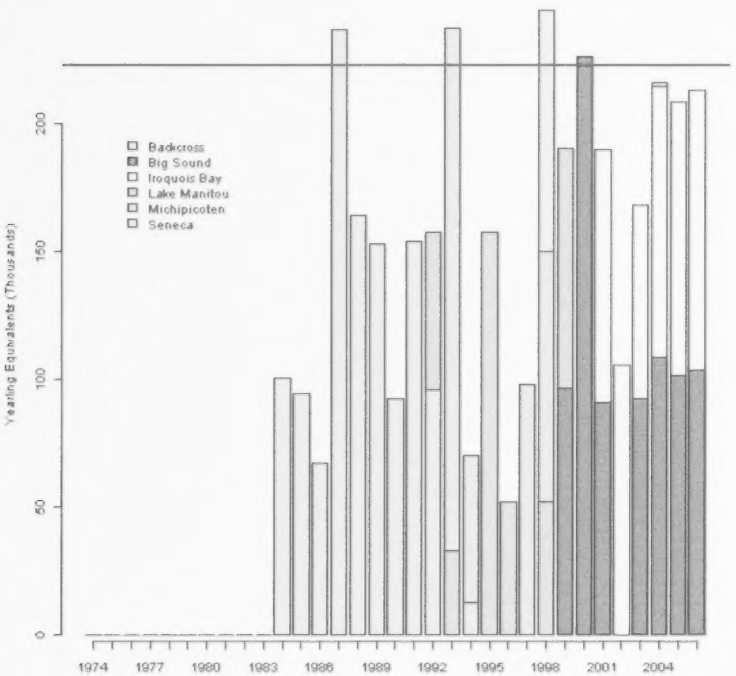

Figure 25. Stocking history for lake trout and backcross in LTRZ 2, 1974 to 2006. The horizontal line represents 2.5 yearlings/ha target for this rehabilitation zone (OMNR 1996).

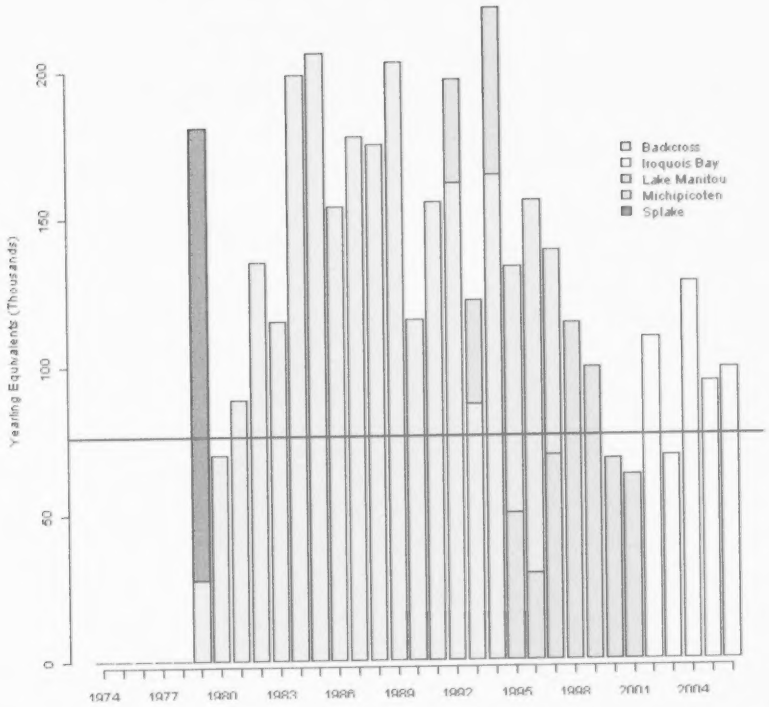

Figure 26. Stocking history for lake trout and backcross in LTRZ 3, 1974 to 2006. The horizontal line represents the 2.5 yearlings/ha target for this rehabilitation zone (OMNR 1996).

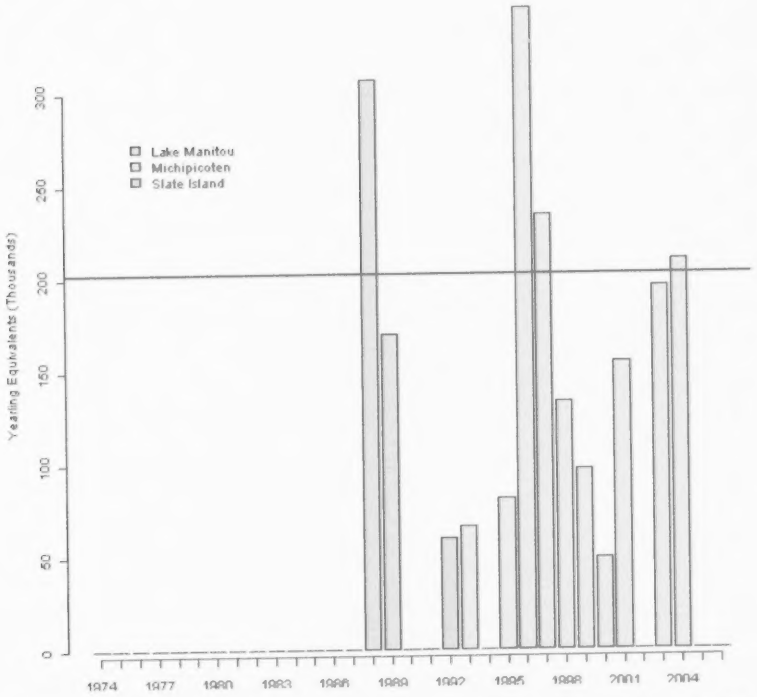

Figure 27. Stocking history for lake trout and backcross in LTRZ 4, 1974 to 2006. The horizontal line represents 2.5 yearlings/ha target for this rehabilitation zone (OMNR 1996).

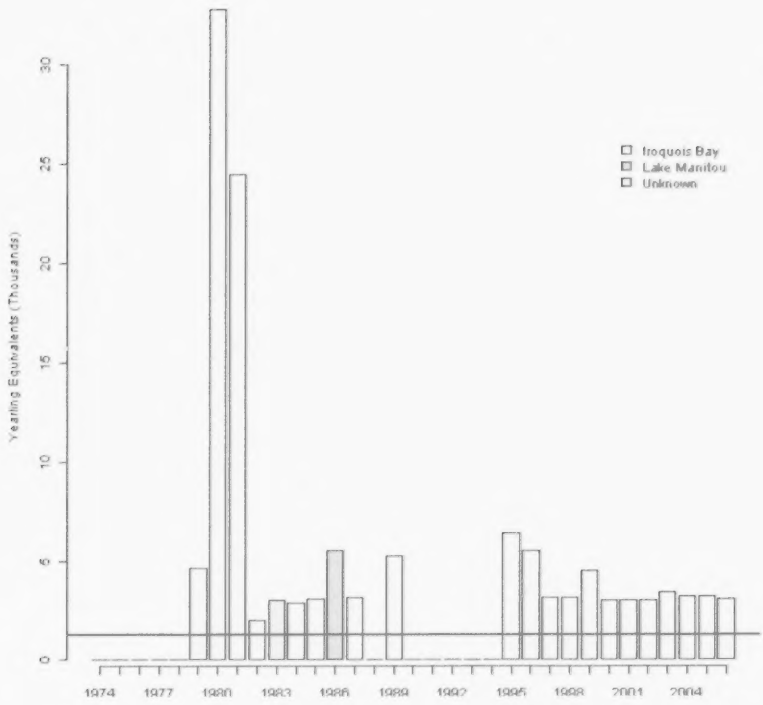

Figure 28. Stocking history for lake trout and backcross in LTRZ 5, 1974 to 2006. The horizontal line represents 2.5 yearlings/ha target for this rehabilitation zone (OMNR 1996).

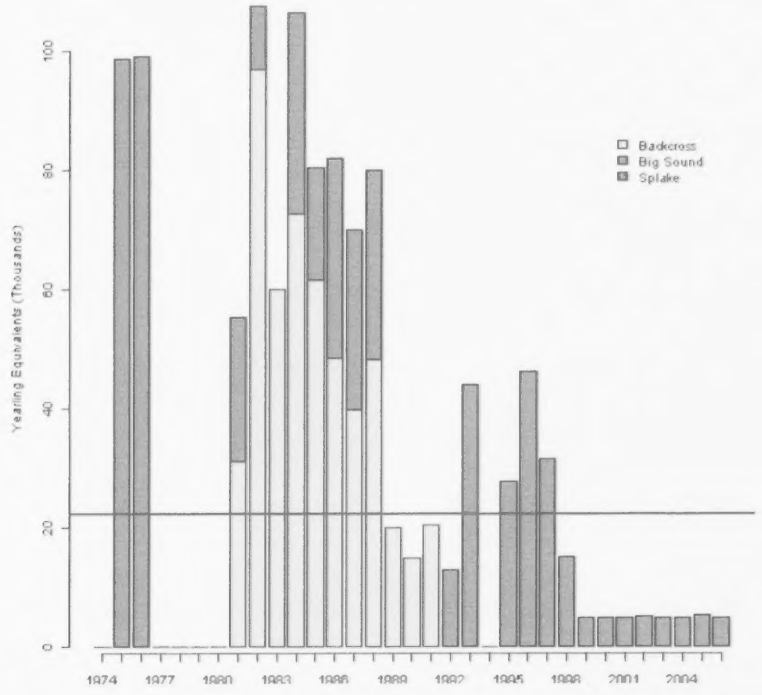

Figure 29. Stocking history for lake trout and backcross in LTRZ 6, 1974 to 2006. The horizontal line represents 2.5 yearlings/ha target for this rehabilitation zone (OMNR 1996).

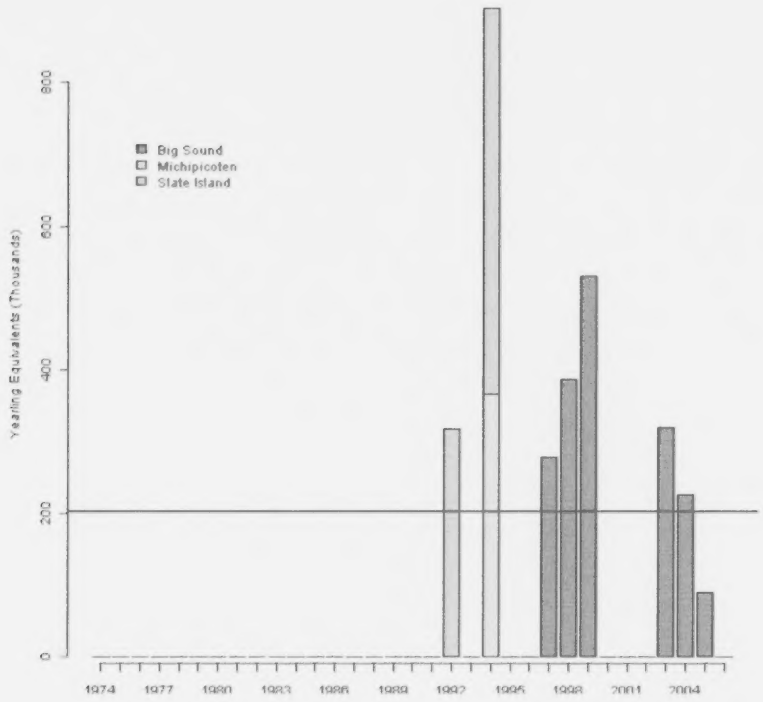

Figure 30. Stocking history for lake trout and backcross in LTRZ 7, 1974 to 2006. The horizontal line represents 2.5 yearlings/ha target for this rehabilitation zone (OMNR 1996).

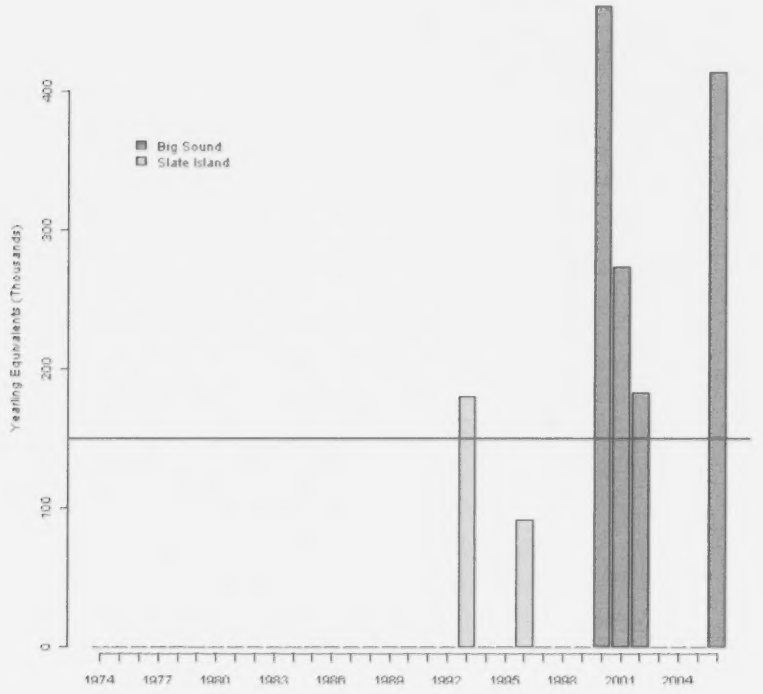

Figure 31. Stocking history for lake trout and backcross in LTRZ 8, 1974 to 2006. The horizontal line represents 2.5 yearlings/ha target for this rehabilitation zone (OMNR 1996).

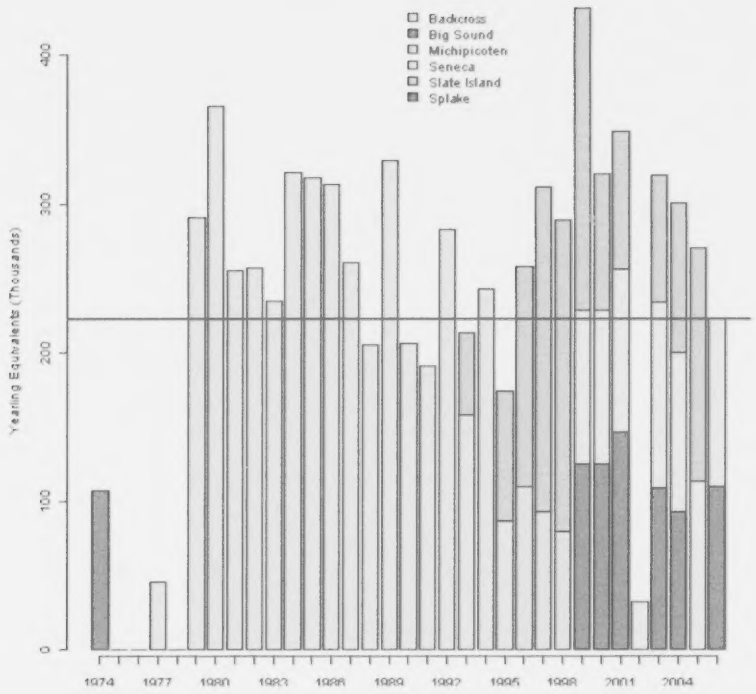

Figure 32. Stocking history for lake trout and backcross in LTRZ 9, 1974 to 2006. The horizontal line represents 2.5 yearlings/ha target for this rehabilitation zone (OMNR 1996).

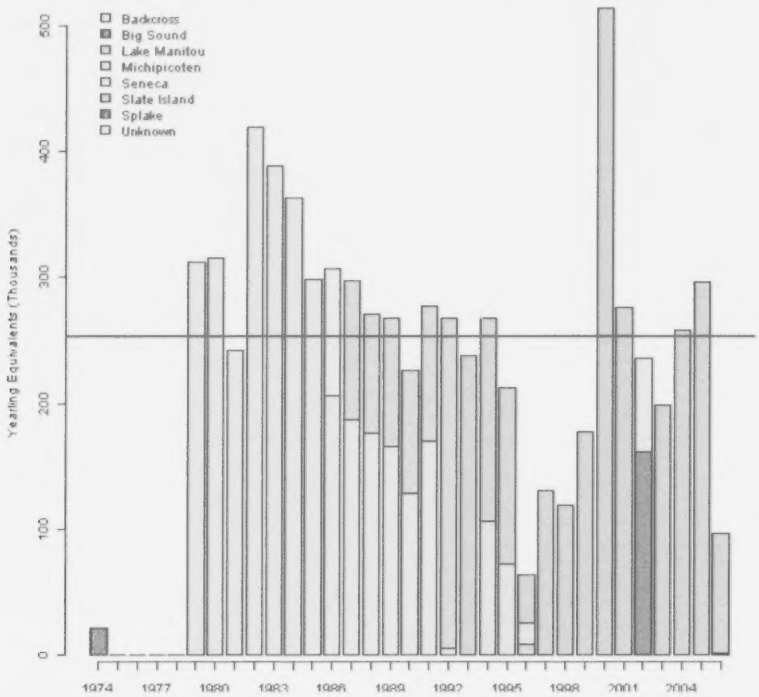

Figure 33. Stocking history for lake trout and backcross in LTRZ 10, 1974 to 2006. The horizontal line represents 2.5 yearlings/ha target for this rehabilitation zone (OMNR 1996).

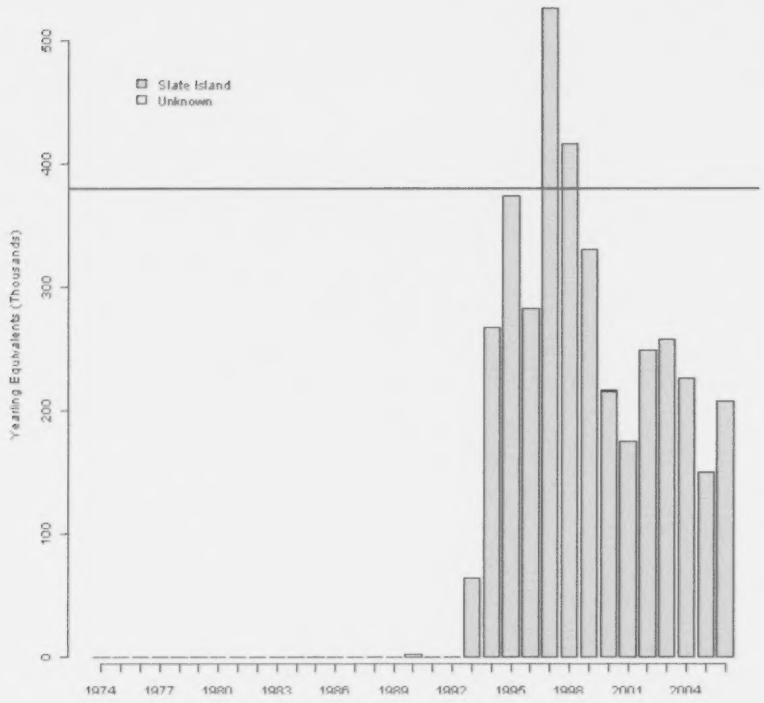

Figure 34. Stocking history for lake trout and backcross in LTRZ 11, 1974 to 2006. The horizontal line represents 2.5 yearlings/ha target for this rehabilitation zone (OMNR 1996).

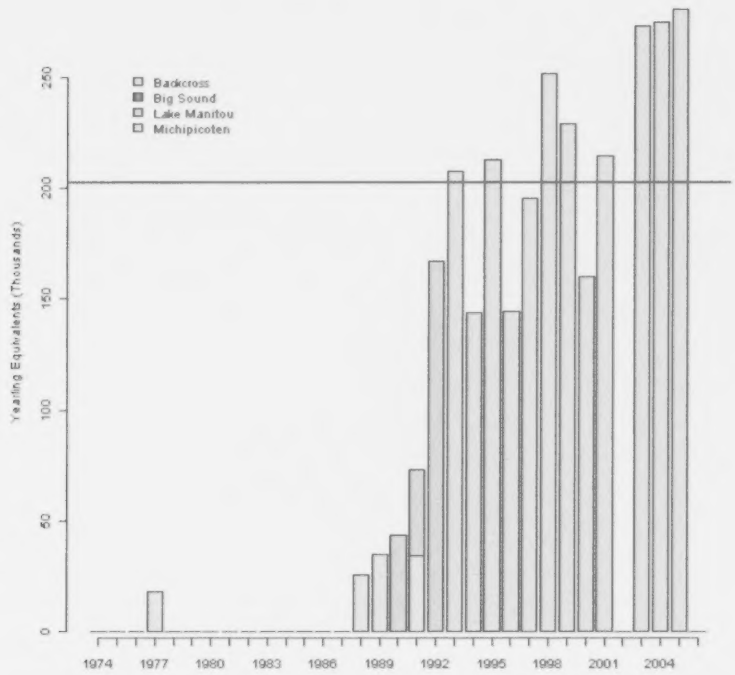

Figure 35. Stocking history for lake trout and backcross in LTRZ 13, 1974 to 2006. The horizontal line represents 2.5 yearlings/ha target for this rehabilitation zone (OMNR 1996).

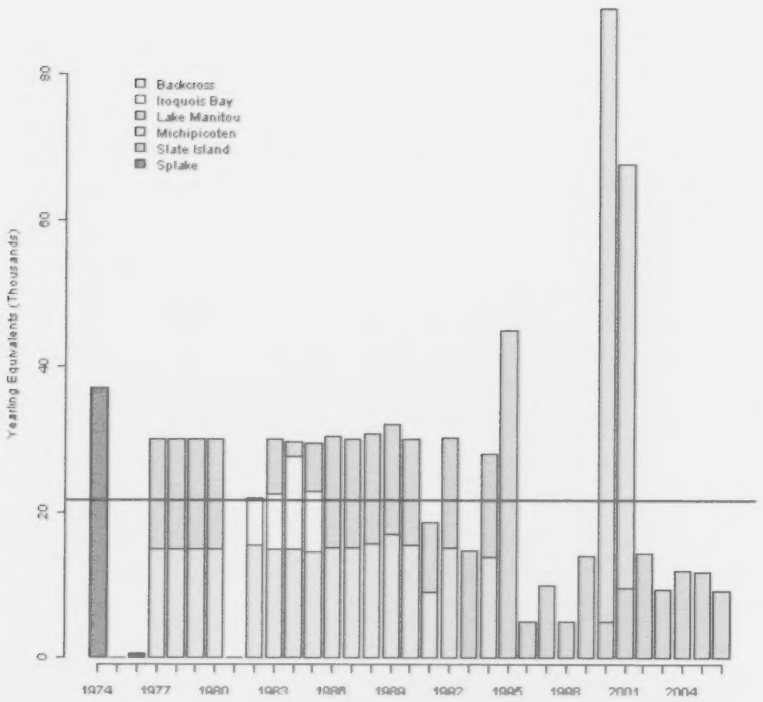

Figure 36. Stocking history for lake trout and backcross in LTRZ 15, 1974 to 2006. The horizontal line represents 2.5 yearlings/ha target for this rehabilitation zone (OMNR 1996).

APPENDIX 2

Scoring matrix used to develop a ranked list of LTRZs for rehabilitation efforts in Ontario waters of Lake Huron.

Table 4. Scoring matrix used to rank LTRZs in Ontario waters of Lake Huron.

			Scoring attribute							
			Existence of a remnant stock	Exploitation control is possible	Low lamprey mortality	Observation of unmarked fish	Stocking target met consistently	Proximity to a remnant stock	Total Score	Rank
LTRZ Number	Common Name	Basin	Score							
6	Parry Sound	Georgian Bay	2	2	2	2	1	1	10	1
5	Iroquois Bay	North Channel	2	2	2	2	1	1	10	2
15	South Bay	Main Basin	0	2	2	2	1	0	7	3
7	Limestone Islands	Georgian Bay	0	2	2	0	1	1	6	4
3	Fraser Bay	North Channel	0	1	2	1	1	1	6	5
4	Grand Bank/Dawson Rock	Georgian Bay	0	2	2	0	0	0	4	6
16	Six Fathom Bank	Main Basin	0	2	0	1	1	0	4	7
10	Owen Sound/Colpoys Bay	Georgian Bay	0	1	0	2	1	0	4	8
12	Western Bruce Peninsula	Main Basin	0	0	2	1	1	0	4	9
9	Nottawasaga Bay	Georgian Bay	0	0	2	0	1	0	3	10
8	Watcher Islands	Georgian Bay	0	0	2	0	1	0	3	11
14	SW Manitoulin Island	Main Basin	0	0	2	0	1	0	3	12
13	Bruce Archipelago	Georgian Bay	0	0	2	0	1	0	3	13
18	Eastern Bruce Peninsula	Georgian Bay	0	0	2	0	1	0	3	14
17	North Lake Huron Humps	Main Basin	0	0	2	0	1	0	3	15
11	Point Clark	Main Basin	0	0	2	0	0	0	2	16
1	Western North Channel	North Channel	0	0	0	0	1	0	1	17
2	Darch Islands	North Channel	0	0	0	0	0	0	0	18

APPENDIX 3

Description of assessment protocols and gear used for lake trout assessment by the UGLMU.

Table 5. Description of assessment protocols and gear used for lake trout assessment by the UGLMU.

Assessment Tactic	Description
Fall Spawning Index Trapnet (FSIT)	• **Net Characteristics** – 8' trap nets. Proportions of 8' trap nets established by scaling up the dimensions of a standard 6'NCIN trap net • **Set duration** – 24-96 hrs. **Sets per day** – 1-3 **Sets per area** – 1 **Area assessed** – 1-3 spawning shoals. • **Set Orientation** – perpendicular to shore **Set location** – near shore, start onshore, max. depth approx. 4 m. • **Set Criteria / time period** – Fixed sites on spawning shoals, fall, surface temperature less than 15°C • **Crew / vessel** – 2-3 person, 5 to 7 m. vessel
Fall Littoral Index Gill Netting (FLIN)	• **Net Characteristics** – clear nylon monofilament gillnets, floats and leads sewn to float and lead lines, panel height = 1.8 m., 3 distinct gangs – 38 mm, 51 mm and 64 mm mesh, each gang is 50 metres long **OR** • nylon monofilament gillnets, double knotted, double selvedge top and bottom, braided integrated lead and float lines, lead line longer than float line, light green colour, panel height = 2.4 m., panel length = 15.2 m., 3 distinct gangs – 38 mm, 51 mm and 64 mm mesh. • **Set duration** – 1.5 hrs. **Sets per day** – 9 **Sets per area** – 90 **Area assessed** - 7000 ha. • **Set Orientation** – perpendicular to shore **Set location** –Depth stratified, nearshore sites starting on shore. • **Set Criteria / time period** – sites randomly selected, fall, surface temperature less than 13 C • **Crew / vessel** – 2 person, 5 to 6 m. vessel • **Reference** - Manual of Instruction – SLIN 1999, Frank Hicks, ISBN – 0-7778-8402-x http://mnronline.mnr.gov.on.ca/spectrasites/Viewers/showarticle.cfm?id=14D66364-7042-4EEC-8D524BF22F32449E&method=DisplayFull_r&ObjectID=14D66364-7042-4EEC-8D524BF22F32449E
Offshore Index Assessment (OSIA)	• **Net Characteristics** – clear nylon monofilament gillnets, floats and leads sewn to float and lead lines, panel height = 1.8 m., Nine panels – 15 m panel of 32 mm mesh, 25 m panel of 38 m mesh, followed by 50 panels of 51 mm, 64 mm, 76 mm, 89 mm, 102 mm, 114 mm, and 127 mm. 140 and 152 mm panels added after 2007. • **Set duration** – 24 hrs. **Sets per day** – 3 (2 prior to 2003) **Sets per area** –25-30 **Area assessed** -17,000 to 58,000 ha • **Set Orientation** – perpendicular to depth contours. **Set location** – 10 m to > 100 m. • **Set Criteria / time period** – Nets are set in pre-defined depth strata. • **Crew / vessel** – 3-4 person, 25 to 30 m. vessel • **Reference** – Offshore Index Assessment Program, 2006 Summary Report, Upper Great Lakes Management Unit, Report: PS-LHA-IA06-SUM
Short Set Gill Netting (SSGN)	• **Net Characteristics** – clear nylon monofilament gillnets, floats and leads sewn to float and lead lines, panel height = 1.8 m., 2 distinct gangs – both 64 mm mesh, each gang is 50 metres long • **Set duration** – 2 hrs, at night. **Sets per day** – 6-8 **Sets per area** – 1 **Area assessed** – 12,000 ha. • **Set Orientation** – perpendicular to shore **Set location** – near shore, start onshore in 1-1.5 m depths • **Set Criteria / time period** – sites randomly selected • **Crew / vessel** – 2-3 person, 5 to 7 m. vessel
Large Mesh Gill Netting (LMGN)	• **Net Characteristics** – clear nylon monofilament gillnets, floats and leads sewn to float and lead lines, panel height = 1.8 m., Five panels per gang– 50 m panels of 102 mm, 114 mm, 127 mm, 140 mm and 152 mm mesh. Panel locations in nets assigned randomly. • **Set duration** – Overnight. **Sets per day** – 4-5 **Sets per area** – 1 **Area assessed** – 12,000 ha. • **Set Orientation** – perpendicular to shore **Set location** – near shore, start onshore in 1-1.5 m

depths

- **Set Criteria / time period** – sites randomly selected

Crew / vessel – 2-3 person, 5 to 7 m. vessel